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RAND CORPORATION,
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Qualitative Constraints on Conventional Armaments: An Emerging Issue

S. J. Dudzinsky, Jr., and James Digby

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This report addresses the question of whether or not qualitative constraints on conventional armaments are desirable, feasible, and acceptable ways of promoting U.S. national security objectives. Discussion centers around possible U.S.-SU agreements and emphasizes the arms control implications of new-generation conventional arms, which include precision-guided munitions and remotely piloted vehicles. Incentives for constraints include (a) enhancement of U.S.-SU security and that of their allies; (b) prospects for resource economies; (c) elimination of catastrophic instabilities. The most restrictive form of qualitative constraints would prohibit development, testing, production, and operational deployment of weapons systems that fit into an agreed-upon performance category. Combined qualitative-quantative constraints, however, have aspects that may be more acceptable to the United States. Over the short and medium term, it is important to consider constraints on large, traditional, penetration weapons systems that are becoming more expensive and more vulnerable to precision weapons. Over the long term, small, efficient modern weapons are the ones that must be dealt with and which governments--ultimately--must control. (DGS)

PREFACE

This report was prepared for the Military Affairs Bureau of the United States Arms Control and Disarmament Agency. It is the final report on an initial exploration of the question of whether or not qualitative constraints on conventional armaments are desirable, feasible, and acceptable ways of promoting United States national security objectives in the long run. The emphasis is on the arms control implications of new precision-guided munitions (PGMs) and remotely piloted vehicles (RPVs), including both the difficulties and opportunities presented by the rapid development of a wide variety of such weapons.

The report has been written to serve officials in the Arms Control and Disarmament Agency, the Department of State, and the Department of Defense, for whom it collects ideas and data on new weapons systems and suggests analytic approaches for dealing with possible qualitative constraints. It should also be of interest to the academic community, since it suggests research on an improved analytic method and theoretical constructs.

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SUMMARY

This report is concerned with the question of whether or not qualitative constraints on conventional armaments are desirable, feasible, and acceptable ways of promoting United States national security objectives in the long run. The discussion is centered around possible U.S.-SU agreements and emphasizes the arms control implications of the new generation of conventional arms, which includes precision-guided munitions (PGMs) and remotely piloted vehicles (RPVs). Our theme is that a better understanding of how the new generation of arms works, what sorts of postures are likely to be efficient, and how these postures relate to the needs of the two sides can help us to identify aspects of the competition where curbs on arms growth will be *mutually* beneficial. Limitations founded only on shallow understandings of these weapons, or that turn out to provide one-sided advantages, can have only a transitory effect, and the process of recovery could lead to even more dangerous instabilities.

We believe that the topic treated is timely. The past several years have seen many new weapons introduced into practical use that are qualitatively different, notably in their precision, whereas many of the more traditional weapon types are escalating in cost and are becoming, at the same time, more vulnerable. Moreover, consideration of the build-up of new arms in the United States and Soviet Union may shed light on the build-ups of some increasingly powerful arsenals in other countries.

INCREASING IMPORTANCE OF THE CONVENTIONAL BALANCE

In recent years, those concerned with arms control have mostly centered their attention on the strategic nuclear competition between the United States and the Soviet Union. But now that strategic parity has become a fact, it has become much more important to consider the balance of nonnuclear forces between the superpowers. Three reasons why it is more important to consider this nonnuclear balance can be noted. First of all, it is less feasible to use American nuclear

superiority to deter aggression. Second, the great build-up of nonnuclear forces by the Soviet Union has strained U.S. relations with some of its allies. Third, it is increasingly perceived that the greatest nuclear danger may be a nonnuclear war getting out of hand, and this in turn might come from an instability in the balance of conventional forces.

It is not only important to consider the balance of conventional arms, but it is necessary to pay increased attention to their limitation and how certain types may enhance or degrade stability. This can best be done if considerable background is available on the mechanics of the new weapons, how well they work against the more traditional weapons, and the costs of the main classes.

Because the literature on conventional arms control is not very extensive, we have tried (in the body of this report) to provide reference data and to suggest sources. Missile ranges and accuracies are given numerically wherever possible, and both investment and operating costs are given for many weapons. The report also includes excerpts from several sources that give data on conventional arms or provide concise information on the factors needed for analysis.

INCENTIVES FOR CONSTRAINTS; SOME TYPES OF CONSTRAINTS

In the context of the arms competition between the United States and the Soviet Union, there are several incentives for attempting constraints on conventional weapons. These include:

- The enhancement of the security of the two parties and their allies.
- The prospects for economies, measured in terms of resources saved.
- The elimination of catastrophic instabilities.

The present research is primarily concerned with "qualitative constraints," which are defined as

> constraints that would limit the development, testing, production, or operational deployment of weapons systems that fit into an agreed-upon performance category.

But we recognize that in virtually any qualitative limitation there will be inherent quantitative aspects or implications, and the reverse will normally also be true.

Under the terms of this project, our research did not include an examination of limitations on nuclear weapons, strategic systems, chemical and biological weapons, and "exotic" systems, such as laser beam weapons. Dual-purpose weapons that could deliver either nuclear or nonnuclear weapons, however, were included. We considered explicit as well as implicit agreements, and, in fact, we believe that the explicit form, in which formal negotiations involve legalistic arguments over the exact wording of written agreements, might often be less suited to the interests of the United States than an implicit understanding. It would appear that the Soviets are more able, given their system, to treat loosely the constraints imposed by agreed-upon language than is the United States. Thus the United States might do better with an implicit understanding, in which there are substantial communications between the parties, but minimal pettifoggery. A good goal is to seek out mutually beneficial constraints and develop a good understanding of their implications over the long run. These would preferably be constraints in which abrogation would clearly be against the interests of the abrogating party. (To illustrate, can arms control analysts find understandings that would be parallel to the rule that requires automobile drivers to stay to the right of the dividing line of a highway?) In many ways the new generation of arms may provide hope for new understandings. This is so both because they may be making older weapons obsolete and because they may be causing strategy and tactics to be revised toward a greater precision in military effects as well as in objectives sought and signals conveyed. These opportunities can be kept in mind while considering the properties of the new weapons, discussed below.

THE NEW WEAPONS AND THE TECHNOLOGY BEHIND THEM

Major changes are taking place in the capabilities of a number of classes of nonnuclear weapons. Some observers believe that these changes will transform the nature of conventional warfare, and that, a dozen or more years from now, many of the systems that have been mainstays since

the beginning of World War II will be obsolescent. In particular, there have been developments in PGMs, in RPVs that can be launched from a variety of platforms, and in mobile air defense systems. New designs of efficient and hard-to-track cruise missiles can function as either PGMs or RPVs. This overlapping of designations suggests that some definitions would be useful. A PGM can be defined as

> a guided munition whose probability of making a direct hit on its target at full range (when unopposed) is greater than a half. According to the type of PGM, the target may be a tank, ship, radar, bridge, airplane, or other concentration of military value.

Note that this definition does not exclude precision-guided missiles of long range--even intercontinental range--but it does assume a mission ending in impact, with the munition generally guided all the way to impact.

An RPV is probably best defined in a very simple way:

> A vehicle that is piloted from a remote location by a person who has available much of the same piloting information that he would have if he were on board.

Although a variety of PGMs and RPVs are under development in both the United States and the Soviet Union, a present-day appraisal would show that actual numbers procured (at least by the United States), for all but three or four types, is quite small. Thus, while major changes in conventional warfare are implied, it is well to keep in mind that they are potential changes, not changes already in hand.

The new systems have been particularly facilitated by three technical developments:

1. The use, in practical systems, of electromagnetic transmitters and receivers operating at much higher frequencies than those used in the past; among other things, this leads to an improvement in angular resolution that makes guidance systems more accurate.

2. Continued development of microelectronic circuits (notably LSI--large-scale integrated circuits) that permit highly complex signal-processing and storage functions to take place in small, reliable, and relatively rugged devices.
3. The development of highly efficient warheads that have great destructive potential but are light in weight.

These technical developments, used in concert, have already resulted in some military hardware with capabilities unheard of in the recent past. For example, the development of practical airborne lasers that use frequencies so high--i.e., wavelengths so short--that they are typically just below the spectrum of visible light has made it possible to guide weapons with angular accuracies approaching those of a high-powered rifle. When the signals reflected from a laser-generated spot that an individual has pointed at a target are processed by microelectronic circuitry, a very compact and effective guidance system can be used to steer a missile to within a few feet of a target from a launch distance on the order of 10 mi. It is just this combination that is being used in the new laser-guided Maverick antitank weapon system. But Maverick carries a very heavy warhead for its task, about 130 lb, and the whole round weighs about 460 lb. If the third development cited above, namely, new efficient designs for small high-explosive warheads, had been incorporated in this design, a missile with adequate lethality against tanks, but significantly lighter in weight, could have been built.

On the other hand, there have been major increases in the cost of a number of other weapon systems--especially those systems that have multiple functions and are an integral, interwoven part of high-performance vehicles intended for use directly in the arena of combat. These include deep-penetration fighter-bombers, new tanks, and nuclear-powered aircraft carriers. The latest models of some of these weapons systems, though very capable, cost a great deal more than the systems they were designed to replace.

Even as procurement costs for these traditional weapons systems have risen, so have the costs of manpower. The average cost per man

in the American forces has increased from $3350 in 1955 to $11,000 in 1975. Thus it is important to look for ways of introducing qualitatively improved equipment to increase the productivity of each man.

IMPLICATIONS OF THE NEW PRECISION WEAPONS

It is important that those concerned with arms limitations consider the implications of the new technology of precision guidance. Here we give only a capsule treatment. Perhaps the essential statement about this class of weapon is this:

> Accuracy is no longer a strong function of range; if a target can be acquired and followed during the required aiming process, it can usually be hit. For many targets hitting is equivalent to destroying.

Notice, though, that even this brief statement implies that a number of things can go wrong. For one, the process of target acquisition may not be easy. Even for targets that are acquired, it may be difficult to track the target with presently deployed equipments, most of which use visual or near-visual wavelengths. Bad weather, battlefield smoke, camouflage, or other obscurants may prevent tracking at any but very short ranges. In some cases, efficient employment depends on a good command-control system, and some current systems are better known for their deficiencies than for their virtues. An opponent can take countermeasures against the PGM or its crew--some technical in nature and some tactical, such as evasion by the target during the missile's flight or attacks on the PGM while it is trying to guide the missile.

These chances for poor performance should be kept in mind while considering the following characteristics of PGMs and RPVs:

- Many PGMs and RPVs, when used under proper conditions, appear to have a much greater military effectiveness than earlier systems (even when compared with quite expensive alternatives that do not use precision guidance). However, there are some situations in which their effectiveness is limited--and those should be faced squarely.

- Many PGMs and RPVs are relatively cheap--cheap to develop, to procure, and to operate. But to understand the full cost implications, the context of their place in the posture and the circumstances of use is needed.
- Many of these new weapons could be developed and manufactured using the facilities and production methods available in most developed countries. Others, which may be very useful, require advanced industrial facilities.
- There may be important consequences for logistics deriving from the small size but great effectiveness of the new weapons.
- Many of the new types of weapons could be moved quickly and in quantity to the places where they are needed most--if there were means at hand to move them.
- Many of the present PGMs and RPVs are particularly useful to the side that is, at the tactical level, on the defense. In a decade or so, new generations of PGMs and RPVs (particularly of longer range) will be well-suited for offensive tactics.
- Even the largest PGMs and RPVs (e.g., the sea-launched cruise missile) can be hard to detect and their carriers can be effectively disguised. They can be launched from a wide variety of platforms without affecting terminal accuracy. The era of relying on aerial and space reconnaissance for verification of agreements may be coming to a close.
- There are important political consequences stemming from the new weapons. They will be able to destroy many military targets that formerly required nuclear weapons, with less collateral damage to civil targets. Thus the nuclear threshold may be raised.

From the point of view of arms limitations, these implications lead us to speculate that

> PGMs and RPVs may provide the impetus to arrive at qualitative constraints on larger, and more complex and costly weapons systems.

If it can be demonstrated that advantages of some of the major offensive weapons are likely to be offset by PGMs, then nations might be more willing to slow the introduction of these major weapons into their forces or even to phase out existing equipments that have a high cost of upkeep.

A second possibility for arms control may be equally important. The fact that the accuracy of precision weapons and their relatively small warheads can lead to less collateral damage opens up the opportunity for agreements, or implicit understandings, that would strictly limit civilian damage in a conventional conflict. Abiding by such an undertaking may be an efficient way for military forces to operate, as they did for hundreds of years, as well as being morally attractive and mutually beneficial to both adversaries.

DECIDING ABOUT CONSTRAINTS

Decisions about qualitative constraints will depend on the answers to questions at several levels: (1) What are candidate systems for agreement or understanding? (2) What are the incentives for the United States (and for the Soviet Union) for a particular agreement? (3) Do qualitative constraints seem useful to pursue as a general class?

By and large, these questions can be addressed in terms of three criteria: desirability, feasibility, and acceptability. Here desirability refers to an objective and analytical evaluation of the net incentives for agreement, whereas acceptability refers to whether or not the agreement is politically palatable. Feasibility refers to the ability to monitor, inspect, and ensure compliance with the agreed-upon terms. An agreement or understanding, to endure, must continue to meet all three criteria from the viewpoint of both parties: it must be desirable *and* feasible *and* acceptable.

Our research suggests that a heuristic approach is likely to be useful for so complicated an evaluation. In other words, hypotheses about the consequences of possible constraints would be constructed and then tested and retested. Our research has suggested three approaches for testing hypothesized constraints. The first is to break down the three criteria into a number of subcriteria; in other words,

to use a systematic and detailed checklist approach. The second approach is to paint a picture of land, sea, air, and space warfare of 15 to 20 years from now in an attempt to identify weapon systems that will not be needed by that time or that will be needed only in small numbers for special purposes. These systems might be good candidates for qualitative constraints. However, there is a complicating factor in this approach: because of new developments, otherwise outmoded systems just might be useful longer than envisioned. For example, the B-52 with air-launched cruise missiles may remain effective much longer than B-52s alone, and carrier-based aircraft with standoff launch capability may serve very effectively compared to deep-penetration aircraft.

The third approach involves (a) constructing models of future U.S.-Soviet confrontations, both with and without the constraints being studied, and (b) posing a series of test questions to determine the impact of the postulated constraints. Actually, all of these approaches need to be considered simultaneously. All are quite rudimentary; we have made no major contributions to analytical technique.

Throughout these evaluations, one of the most important tasks of analysts will be to identify limitations that might foreclose systems whose value cannot be known until later.

WORKING WITH ASYMMETRIES

While the complexities of decisions to constrain conventional arms, and the difficulties of evaluating proposals, may result in some suggestions for exactly symmetrical arms limitations by the two superpowers, we believe that the most promising direction lies elsewhere. To get the greatest value--as rated by the value systems of each side--any agreement or understanding will probably have to be asymmetrical.

The military balance between the United States and the Soviet Union has always been characterized by asymmetries--aspects that reflect different value systems on the two sides. America has generally been well ahead of the Soviet Union in advanced technology, especially relative to offensive forces at sea or in the air, whereas the Soviets have maintained larger land forces and more extensive antiaircraft and coastal defenses.

Many of these asymmetries have been a natural product of geography and history, and each side has opportunities and problems conferred by its geographic position. For example, the Soviet Navy--with minor exceptions--operates from home ports separated from the open oceans by narrow seas and straits, and until recently they have neglected the long-endurance bluewater ships that the U.S. Navy emphasizes. The United States, on the other hand, has been forced by its location to develop ways of transporting military forces and their supplies over great distances, and has much more highly developed air and sea transport systems. (Although still true, this is an area where the Soviets have shown great improvement, as evidenced by their performance during the Arab-Israeli War of October 1973.) In addition, each side's history (its good and bad experiences) has affected its present-day practices.

It is important to recognize these asymmetries and the openings they may provide for qualitative constraints in conventional armaments. For example, since the Soviet Union does not currently build large aircraft carriers, it would not be productive to seek a symmetrical agreement in this area. On the other hand, past Soviet postures have shown a grave concern over the threat from *our* aircraft carriers, so they may be willing to reduce the number of a given quality of attack submarines in exchange for our reducing the number of aircraft carriers that exceed certain performance characteristics.

The most restrictive form of qualitative constraint would prohibit the development, testing, production, and operational deployment of weapons systems that fit into an agreed-upon definition. However, a combination of qualitative and quantitative constraints, where the numbers of systems having certain qualities are not reduced to zero but rather to an agreed-upon quantity, is another possibility. Such constraints have several aspects that may enhance their acceptability to the United States. They could be applied at either the production or deployment level. From the U.S. point of view, such agreements would be less dependent on the exceedingly difficult verification of what is happening in Soviet laboratories or testing grounds. At the same time, the United States could carry qualitatively advanced weapons to the point of pilot production and depend on our relatively strong capabilities for mass production of the most recently developed weapons to

save the day if it were found that the Soviets had abrogated the agreement--and if there were time. Moreover, such an agreement would at least achieve some of the economic benefits of limitation, especially the avoidance of large-scale procurement, maintenance, and manpower costs, and at the same time it would permit our industrial technology base to remain at the forefront of the relevant technologies. (However, because we typically spend 15 to 25 percent of total procurement funds prior to large-scale production, defense contractors would have to raise unit prices to stay in business.) In the United States, this kind of agreement might also be more acceptable from a political point of view, since plants would not be shut down.

In the course of recent debates on new military technology, Albert Wohlstetter has compared those who are now calling for severe restrictions on such development with the Luddites, the group in 19th century England who sought to hold back the industrial revolution by destroying machines. We believe such restrictions are often wrong for the United States; they can, in some cases, run against important aims of arms control. This is because new technology can sometimes lessen the resources going into arms. It may also permit a new precision in the physical aiming of weapons, which in turn permits a new precision in the purposes for which military forces are applied. New technologies can--potentially--make forces less vulnerable, more responsive to political control, and possibly less costly. In fact, the new technologies of precision guidance suggest that there may be a common ground between the political elements in the United States who have been identified as opposing larger defense expenditures and those whose main interests have been in the improvement of U.S. defenses.

Thus in seeking candidates for limitation among conventional arms systems over the *short and medium term*, it seems to us that it is particularly important to consider constraints on the large, penetrating weapons systems of traditional types (for the United States, these include, for example, the XM-1 tank, the CVN, and the F-111D), which are becoming both more expensive and in some cases more vulnerable to precision weapons. As a consequence, these generic types may become self-limiting. This may take 10 years or 30 years, but it seems likely if

not inevitable. If so, why should ACDA bother to consider weapons in this category? First, a great deal of money might be saved by anticipating this trend, just as a great deal was saved during the life of the Washington and London Naval Treaties, which mainly confirmed the politically inevitable. Second, overall, there is uncertainty as to how the trend will go with time, tempered by the fact that the traditional systems can be the platforms for the most efficient modern weapons, whereas their vulnerabilities can be postponed through the suppression of their natural enemies. This points up the need for a careful analysis of penalties and benefits. But if ACDA is to do the doable, this seems to us the *immediate* area where agreements or understandings should be explored.

Over the *long term*, however, the arms control specialist must learn how to deal with the small and efficient modern weapons, a class that includes many weapons that will defy present detection techniques, that may exist in great numbers, and that can be employed with great effect. These are the weapons about which analysts need to learn more, for which limitations must be explored along new conceptual pathways, and which governments--ultimately--must control.

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PART ONE: INTRODUCTION

I. DEFINITIONS, RATIONALES, AND INCENTIVES

Arms competitions, as well as attempts to limit arms, have traditionally been categorized as strategic nuclear, tactical nuclear, and conventional. Of these categories, the attention of governments and analysts in the arms control community has, in recent years, been centered on nuclear armaments, with emphasis on the strategic nuclear competition between the United States and the Soviet Union. This is, of course, as it should be, since controlling the risks of general nuclear war must remain our highest priority. On the other hand, it has been widely noted that the emerging nuclear parity between the United States and the Soviet Union has greatly reduced the credibility of a nuclear retaliatory threat to deter aggression. In the past, in any really serious crisis, there was the implicit threat that the United States might use its overwhelmingly superior arsenal of nuclear weapons. The Cuban missile crisis, for example, seemed to prove that in a crunch the Soviets would be forced to back down. That time has passed. It is unlikely that the United States will manage anything greater than nuclear parity with the Soviet Union in the foreseeable future.

Thus, the role of conventional forces has become more central, and they can be expected to play an increasingly important part in establishing and maintaining an effective deterrent posture, especially in Europe. These forces must be strong enough so that their possessors are not at a disadvantage in bargaining. They must contribute to stability, and, should a crisis or conflict occur, they are the forces that would be used first, perhaps decisively. Their significance is reflected in existing force structures, since expenditures on conventional arms and forces account for over three-fourths of the more than $300 billion that the world puts into defense annually. Almost two-thirds of this $300 billion is spent by the two superpowers, and despite their massive nuclear arsenals, over 80 percent of their respective defense budgets is allocated for conventional forces. The United States alone spent about $35 billion last year on the procurement of conventional hardware

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and on operating and maintaining it.[1] An understanding of what is happening to conventional forces is made both more complex and more pressing because conventional weapons technology is rapidly undergoing fundamental changes made possible by a variety of recent technical developments.

These factors make it even more important that new thought be given to the possibilities for the control of conventional armaments. The fact that the United States can no longer claim a clear nuclear superiority, coupled with recent new developments in conventional weapons technology and the costs of conventional forces (which appear asymmetrically burdensome to the United States), serves to focus greater attention on conventional arms constraints as a method of promoting U.S. national security objectives in the long run. The situation is made even more urgent by the Soviet's steady acquisition of major conventional arms--including armored vehicles, tactical aircraft, improved submarines, and surface combatants--at a time when the conventional forces and equipment levels of the United States and NATO have remained relatively fixed.

In the past, conventional forces have been studied primarily from the relatively simpler viewpoint of possible quantitative limitations (as in the GCD proposals of the 1962-1964 period and in most aspects of MBFR).[2] Little attention has been given, however, to possible limitations on qualitative improvements in conventional arms. Some terms needed for this kind of consideration are defined below.

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[1]The fraction for conventional forces worldwide was estimated by the UN Association in 1974. It apparently divided expenditures into conventional, nuclear, and "other." Expenditures are from *The Military Balance 1975-1976*, The International Institute for Strategic Studies (London), and Donald H. Rumsfeld, *Annual Defense Department Report, FY 1977*. The $35 billion is the sum of Programs II and IV of the latter (pp. 110-111) and does not include research and development or most personnel costs.

[2]General and Complete Disarmament, discussed in Geneva under UN auspices; Mutual and Balanced Force Reduction, currently being discussed in Vienna as a result of a NATO initiative. For a discussion of the former, see Curt Gasteyger, "The Status of the Negotiations on General and Complete Disarmament," *Disarmament*, No. 1, 1964, pp. 5-13.

DEFINITIONS

For the purposes of this report, the term "conventional arms" is defined as[3]

> ... those weapon systems (including their munitions) designed to produce lethal or other destructive effects, other than purely nuclear weapons, strategic systems (ICBMs, SLBMs, and heavy bombers), CBW weapons, and "exotic" systems, such as lasers. Dual-purpose weapons, however, are included. Military equipment, as such (e.g., trucks, reconnaissance aircraft), is not considered as "arms" with the exception of certain categories--such as trucks or APCs with weapons mounted thereon.

The term "*qualitative improvement*" is *defined as*

> ... any change in the characteristics of conventional weapons systems designed to improve their operational capabilities (e.g., in firepower, accuracy, penetration capabilities, survivability, endurance, etc.), as opposed to quantitative changes or changes purely in numbers of weapons without regard for performance characteristics.

A "qualitative constraint" is

> ... one that would limit the development, testing, production, or operational deployment of weapons systems that fit into *an agreed-upon definition.*[4]

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[3]The following excerpts are taken from definitions specified by ACDA, as are several of the examples that follow. "Dual-purpose," in the sense used here, usually refers to systems that could deliver either nuclear or nonnuclear warheads. The task of analyzing arms control proposals has recently been made more complex by efforts to develop "convertibles" *with insertable nuclear components or* "INCs," which would convert high-explosive nonnuclear warheads to nuclear ones. Another distinction is also becoming less clear due to technical developments, especially the possibility of achieving great accuracy at long range: "strategic" weapons can now look just like "tactical" weapons. For example, a cruise missile of given aerodynamic configuration can be made to attack a ship 80 mi away or an electric plant 2000 mi away. It could do either job with nonnuclear or nuclear warheads. The labels "strategic" and "tactical" for such a system only serve to confuse.

[4]In the most restrictive sense, a purely qualitative constraint would *prohibit* the development, testing, production, or operational deployment of weapons having certain qualities.

Thus, a measure whereby the United States and the Soviet Union agreed to defer introduction of a new-generation main battle tank for 10 years would be essentially qualitative in nature; its intent would be not only to avoid the heavy costs of development and procurement in a major area of the arms competition, but also, at least from the viewpoint of the United States, to introduce an element of greater stability in the U.S.-Soviet military relationship by easing our concern over a major component of the Soviet threat to Europe.

Another example of a qualitative constraint would be a measure whereby parties agreed not to produce a next-generation fighter aircraft for 5 years. Such an agreement could result not only in resource savings and a slowdown in the arms competition in the signatory states, but also in a slowdown in regional arms competitions (in terms of reduced opportunities for acquisition of modern, sophisticated weapons systems), which could conceivably lead to lessened tensions in regional trouble spots.

Yet another example of a qualitative constraint is found in the Korean Armistice Agreement of July 1953, under which the parties agreed that combat aircraft, armored vehicles, weapons, and ammunition would be introduced into Korea only on a one-for-one replacement basis, and items so introduced had to be of the "same effectiveness and the same type" (Article II, 13(d)). The intent of this provision was to improve the stability of the armistice.[5]

In virtually any qualitative limitation, as in these three examples, there will be inherent quantitative aspects or implications (and the reverse will normally also be true). Only a very broad quantitative limitation, such as the U.S. GCD Stage III proposal (1962) that all armaments in agreed-upon categories would be reduced by 30 percent, would be a pure quantitative case;[6] as soon as any differentiation among or

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[5]The Communist side subsequently violated this provision by introducing improved models of aircraft and other armaments; to restore the military balance, the United Nations Command announced in the Military Armistice Commission in 1957 that because of the continuing Communist buildup, the United Nations Command was entitled to be relieved of the obligations under Article II, 13(d).

[6]In the case of purely quantitative limitations, a corollary problem arises from the fear of a deflection of the competition into new

within categories of armaments is included, qualitative implications begin to appear. For example, "Each party can have no more than 10,000 tanks (quantitative) of which no more than 1000 can be larger than 50 tons gross weight" (quantitative-qualitative). Qualitative-quantitative constraints are discussed in more detail in Section VI.

This report focuses on qualitative improvements and on constraints that are primarily qualitative in nature, with the realization that most such constraints will have quantitative implications as well.

WHY QUALITATIVE CONSTRAINTS?

In a world where military expenditures continue to rise steadily--in some cases spectacularly, such as in the oil-rich countries--and where enormous sums are spent annually on military research and development, tensions continue to be generated or exacerbated in many areas by the fear that a potential enemy is "getting ahead." What one side considers "modernization" or "force improvement" may seem--and well could be--threatening to his opponent. To the extent that military research and development is successful, this is its payoff. In some cases new generations of weapons may replace their predecessors long before the older generation has been physically worn out. Other new weapons may linger for years in the development phase, generating fears and uncertainties--and even countermeasures--before production has begun.[7] And each new generation weapon is, in most cases, much more expensive than the weapon it replaces. Some, but not all, may cause more widespread devastation, or more damage not directly related to military goals, in

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qualitative improvements, as was the case in the SALT I agreement. This problem also arose as a consequence of the Versailles Treaty and Washington Treaty of 1922, after which Germany constructed "pocket battleships" of unparalleled speed and firepower.

[7] There is, of course, the other side of the argument: that the uncertainties induced in adversary calculations of capabilities and vulnerabilities by continued, unconstrained technological advances are desirable, and that they produce an inherent deterrent capability. That is, new weapons of uncertain performance characteristics may give a rational adversary planner greater cause for caution in his behavior than weapons with a common technological base and known performance characteristics, as might result from a qualitative arms control agreement.

the fashion of the Nazis' V-weapons. On the other hand, modernization of other sorts leads to precision of aim and precision in damage done--so some trends may deserve encouragement.

It is this force modernization process that most directly leads one to consider the possibilities for qualitative constraints on conventional armaments. Some constraints may shape postures so as to lead to an easing of fears, and thus of political tensions (particularly in the U.S.-Soviet case); to a reduction in regional arms competitions and an increase in stability in trouble-spot areas; and generally to establishing a process of conventional arms control as a means of enhancing national security.

Another primary reason for qualitative constraints would appear to be the possibility of achieving significant savings in resources, in view of the historical trend of greatly increased costs of new-generation weapons systems. Generally speaking, almost every new or improved weapon system is substantially more expensive than an existing system of the same type; since these new systems are quite often more effective, cost-effectiveness should also be assessed. Cost considerations are particularly relevant for the United States, where, for the foreseeable future, a major dilemma will be the need to reconcile growing costs of weapons systems (and military manpower) with domestic pressures to reduce defense expenditures. For the Soviet Union, the cost of defense also appears to be rising, as is reflected in estimates of their defense budgets of recent years, and we can reasonably assume that the increased technological sophistication of conventional weapons is a significant factor in driving defense expenditures upwards.[8] The military drain on available national resources impedes economic growth and imposes a high opportunity cost on the civilian economy. As in the United States, there are incentives for a reordering of priorities.

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[8]Part of this apparent increase may be a result of better information and understanding of Soviet defense budgets on our part; part of it is real.

John Erickson discusses Soviet problems with the economic burdens of defense in *Soviet Military Power*, Royal United Services Institute, London, 1971, p. 103. He cites a study by Siegfried Schönherr in *Wirtschafts Wissenschaft* (E. Berlin) of August 8, 1969: "One East German study dramatically illustrated the problem of rising costs, procurement

On the other hand, strong arguments can be raised in favor of unlimited U.S. exploitation of the potential for technological advances in weaponry. Indeed, for the United States to assume a favorable position vis-à-vis qualitative arms constraints, some compelling arguments to the contrary must be overridden. Historically, the technological advantage of the United States in weaponry has contributed significantly to its relative military position; this remains true today. Furthermore, maintaining the ability to substitute improved technology for manpower would seem to be to its comparative advantage in an era of no conscription and rapidly rising manpower costs.

So, while there are some compelling reasons to consider qualitative constraints on conventional armaments, and the topic is very timely, there are also substantial reasons to proceed with great care. In particular, an understanding of the new generation of arms is essential if we are to identify constraints that will be beneficial to each side.

INCENTIVES FOR POTENTIAL PARTICIPANTS

In the remainder of this report, we explore, against the rather complex background just described, the issues involved in determining whether or not qualitative constraints on conventional armaments represent opportunities for promoting U.S. national security interests in the long run. The most critical initial question, as we perceive it, is whether or not qualitative constraints that are *desirable, feasible,* and *acceptable* to both sides can be formulated in the context of the U.S.-SU arms competition.

If a U.S.-Soviet agreement could not be formulated, then qualitative arms constraints agreements among other arms producers, or between other arms producers and Third World arms consumers, would be difficult to

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costs (Anschaffungs Kosten)--taking the 1962-63 price level as '100,' then aircraft are costing '320' on this scale, MBTs '483,' medium tanks '246' and artillery pieces '163'...." (Note that the index numbers in Erickson's book were incorrectly treated as percent increases by J. I. Coffey in his useful *New Approaches to Arms Reduction in Europe*, Adelphi Paper No. 105, The International Institute for Strategic Studies (London), 1974.) See also the appendix by Andrew Marshall in U.S. Congress, *Allocation of Resources in the Soviet Union and China--1975*, Hearings Before the Subcommittee on Priorities and Economy in Government of the Joint Economic Committee, Part I, 94th Cong., 1st Sess., released October 26, 1975, pp. 153-177.

envision. Furthermore, an agreement among certain Third World countries to restrict qualitative arms improvements, while of possible interest to the United States, would not significantly affect the U.S. budget dilemma. This is probably true even in view of the fact that fiscal 1975 U.S. arms export sales exceeded $6 billion[9] and that some of the subsequent cost benefits resulting from large production quantities would be lost if export sales were reduced as a result of such Third World agreements.

It is in this context that we must consider the incentives for U.S.-SU agreement;[10] these include:

- The enhancement of the security of the two parties and their allies.
- The prospect of economies, measured in terms of resources saved.
- The elimination of catastrophic instabilities.

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[9] *Aviation Week & Space Technology*, June 30, 1975, p. 19.

[10] We shall use the word "agreement" to cover both implicit and explicit agreements. In a great many cases, the implicit form, where there is a benefit to both sides in compliance, may be more suited to U.S. interests than a legalistically derived written document. For more on arms control bargaining and the stability of such bargains, see Thomas C. Schelling, *The Strategy of Conflict*, Harvard University Press, Cambridge, 1960, especially pp. 21ff. and pp. 230ff. For a four-way classification, see Andrew Pierre, "Limiting Soviet and American Conventional Forces," *Survival*, Vol. 15, No. 2, March/April 1973, pp. 59-64. Pierre suggests that, in general, constraints would tend to crystallize around four alternatives:

1. *Unilateral*--the simplest, especially if there has been a national decision to reduce armed forces in any case.
2. *Mutual Example*--the expectation would exist, and if necessary be signaled to the other side, that the reductions should be reciprocated.
3. *Informal Negotiations*--the two countries would come to an understanding through bilateral discussions on the size and scope of reductions, but the implementation would be undertaken without formal agreement.
4. *Formal Agreement*--a specific, written agreement between the countries, perhaps in the form of a treaty.

Pierre points out the attractiveness of informal negotiations, which would make it possible for the two governments to reach an understanding without the legal requirements of what would otherwise have to be a very complex treaty and which would also provide the means for an exchange of information on conventional forces and budgets.

Consideration of each of these incentives in itself leads to a large set of researchable issues. (Our study has found that regrettably little solid research has been done.) For example, when one asks whether a qualitative constraint on a particular system--say cruise missiles--will enhance U.S. security, it is necessary to consider which other weapons systems might substitute for cruise missiles. Alternatively, will cruise missiles substitute for systems that strain resources in terms of cost or (for the United States) manpower? To estimate economies, procurement costs alone are not sufficient; one must consider development costs, operation and support (O&S) costs, and the impact on delivery system requirements. It is also important to consider how the presence of a new system may channel the opponent's resource allocations; former Defense Secretary Schlesinger, for instance, pointed out that a good U.S. cruise missile system would encourage Soviet expenditures on defense against air-breathing vehicles, a choice he considered more in the interest of the United States than the buildup of other forces. While in-depth examination of all of these issues is beyond the scope of this report, we do attempt to show how the consideration of constraints can be made more methodical.

With respect to the first incentive for a U.S.-SU agreement--the enhancement of security--there was a temptation to add the phrase "and an easing of tensions," since one feels more secure if tensions are lessened. However, we believe this phrase oversimplifies one of the most important aspects of any agreement: that the security of both parties should be enhanced in a real sense, and not just on the surface.

Our discussion of the second incentive for a U.S.-SU agreement includes some information on a much-neglected aspect of conventional arms agreements, the *long-term* cost implications (by contrast with weapon procurement costs). We also note some ways in which the perception of costs varies between the United States and the Soviet Union.

In considering the third incentive, even though we deal here with possible U.S.-Soviet agreements, it should be noted that a major concern will be that potential catastrophic instabilities may have their roots in Third World countries. The scope of this study did not include the important topic of arms transfers to the less-industrialized countries.

Yet it seems clear that a U.S.-Soviet agreement would affect third-country policies and options in several ways. First, the menu of high-technology weapons available to these countries could be somewhat restricted. There would be a consequent diminution in the opportunities for third-country manufacture of weapons using the restricted technologies. Second, the pattern of a superpower agreement might show the way, by its logic and form, for a regional agreement. Third, if the superpowers agreed to constraints themselves, their position in asking for constraints on the part of other industrial countries would be improved. This is important because, even if the United States and the Soviet Union curtailed arms transfers, some weapons can readily be produced in France, Sweden, England, Italy, etc., notably antitank, antiship, and antiair missiles. And, given the tremendous economic pressures on these other arms producers, it is unlikely that they would give up the international market for qualitatively improved weapons without firm persuasion.[11]

Finally, it should be noted that incentives are not confined to the military-security sphere discussed here, but there are forces at work as disparate as the need for grain, internal political pressures, the personal objectives of national leaders, and the struggle of certain industries for survival. These are the details that emerge as a proposal goes from the general principle to specific agreement. This complexity is a good argument for a structured approach.

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In Part Two we discuss in some detail technological trends in weaponry, trends that are providing both the United States and the Soviet Union with qualitatively improved and increasingly effective nonnuclear arms. A major theme of this report is that analysts must be thoroughly

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[11] Note that while the U.S. Congress imposed various prohibitions on the transfer of certain advanced aircraft to Latin America, the French sold Mirage fighters to Argentina, Brazil, Colombia, Peru, and Venezuela. See Luigi Einaudi et al., *Arms Transfers to Latin America: Toward a Policy of Mutual Respect*, The Rand Corporation, R-1173-DOS, June 1973.

familiar with these new weapons if they are to identify aspects of the competition where constraints would be mutually beneficial to the two sides. These weapons provide hope for new understandings in several ways. In some cases, they may be making certain older weapons obsolete that now contribute to instabilities. They are also causing strategy and tactics to be revised toward a greater precision in military effects as well as in objectives sought and signals conveyed. Thus, we think it useful to deal with them at some length.

PART TWO: A GUIDE TO NEW WEAPONS TECHNOLOGY

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II. A NEW ERA IN CONVENTIONAL WEAPONS TECHNOLOGY

The history of technological change in conventional weaponry has been marked by slow and steady improvements with infrequent breakthroughs that have impacted heavily on the character of conventional warfare. By and large, the spectrum of improvements in conventional weapons can be broken down into three categories:

1. Improved replacements for aging weapons--e.g., replacement of the F-4 by the F-15.
2. Action-reaction--e.g., development of spaced armor for tanks, in reaction to shaped-charge warheads.
3. Entirely new classes of weapons, made possible by the practical application of new high technology--e.g., the laser-guided bomb (LGB) and electro-optically guided missiles (e.g., Maverick).

A superficial view of the dominant features of this spectrum suggests that at one end (improved replacements for aging weapons), the trend has been for conventional weapons to get bigger, more sophisticated, more powerful, and sometimes more provocative--without necessarily providing equivalent advantages in terms of military effectiveness.[1] Whether or not this characterization is accepted as only partly true or as entirely correct, weapons that reflect these characteristics have generally been the focus of conventional arms control. But recently, several technical developments and their use in practical military hardware have resulted in a variety of developments at the other end of the spectrum (i.e., entirely new weapons), which suggests that past trends may be in the process of reversal.[2] What are the most important of these new

[1]Those who argue that the big new weapons are more provocative do so both on the basis of their killing power and because their multipurpose design makes it difficult for a potential enemy to foresee how they will be used.

[2]Weapons developments in the second category--action-reaction--result from developments at both ends of the spectrum, although the most interesting ones (from a technical point of view) and the most intriguing ones

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technical developments, and how are they affecting conventional weapons technology?

QUANTUM JUMPS IN THE CAPABILITIES OF CERTAIN WEAPONS

In the past several years, an unusually large number of significant technological changes have been introduced into practical military hardware, changes that in some cases have already resulted in what we might call quantum jumps in the performance of certain conventional weapons systems. By quantum jumps we are referring, for example, to improvements in kill probabilities on the order of 10 to 100 times, and to the ability of a pilot on the ground to control, accurately, a remotely piloted vehicle flying hundreds of miles away. Improvements such as these may well herald a period of breakthroughs in the third category above, which could result in fundamental changes in conventional warfare capabilities. This hypothesis is reflected in a recent statement by Dr. Malcolm Currie:[3]

> The technology of conventional warfare is undergoing a transformation. We are on the threshold of a new era in which evolving new capabilities will profoundly influence the nature of nonnuclear wars and the way they are deterred.

This assertion arises from recent and rapid developments in such classes of weapons as precision-guided munitions (PGMs), remotely piloted vehicles (RPVs) that can be launched from a variety of platforms, and effective mobile air-defense systems. New designs of efficient and hard-to-track cruise missiles can be either PGMs or RPVs. This overlapping of designations suggests that some definitions would be useful. A PGM can be defined as

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(from an arms-limitations point of view) result from the development of entirely new "high-technology" weapons. These "reaction"-type developments are considered by some analysts to be one major driving function in the force-modernization process. For a particularly specific discussion of seven such driving functions, see Colin S. Gray, "The Urge To Compete: Rationales for Arms Racing," *World Politics*, Vol. 26, No. 2, January 1974, pp. 207-233.

[3] U.S. Senate, Hearings Before the Committee on Armed Services on S.920, Part 6, Research and Development, 95th Cong., 1st Sess., March 7, 1975.

> A guided munition whose probability of making a direct hit on its target at full range (when unopposed) is greater than a half. According to the type of PGM, the target may be a tank, ship, radar, bridge, airplane or other concentration of military value.[4]

Note that this definition does not exclude PGMs of long range--even intercontinental range--but it does assume a mission ending in impact, with the munition generally guided all the way to impact.

An RPV is probably best defined in a very simple way:

> A vehicle that is piloted from a remote location by a person who has available much of the same piloting information that he would have if he were on board.

The term "RPV," if unqualified, usually refers to an airborne military vehicle, though the same techniques are discussed for submarines, tanks, and other vehicles.

By these definitions, some RPVs are also PGMs. Others, including some that carry reconnaissance devices or laser designators, are recoverable and are not PGMs. Both to convey the breadth of the two classes and to indicate something of the progress that has been made, some illustrative examples of PGMs[5] and RPVs are listed in Tables 1 and 2, respectively.

It is beyond the scope of this report to examine any of these new developments in technical detail or to explore the details of countermeasures and counter-countermeasures. We shall, however, describe in broad terms what appear to be the most important technical developments and give some examples of how they have influenced military hardware.

Three technical developments seem to be of particular importance:

1. The use, in practical systems, of electromagnetic transmitters and receivers (or sensors) operating at much higher frequencies

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[4]This definition is slightly modified from one given by James Digby in *Precision-Guided Weapons*, Adelphi Paper No. 118, The International Institute for Strategic Studies (London), Summer 1975, p. 4.

[5]For brief discussions of these PGMs, see James Digby, "PGMs--Changing Weapon Priorities, New Risks, New Opportunities," *Astronautics and Aeronautics*, Vol. 14, No. 3, March 1976, pp. 36-46.

Table 1

ILLUSTRATIVE EXAMPLES OF U.S. AND SOVIET PRECISION-GUIDED MUNITIONS (PGMs)

(Including cruise missiles)

Designation	Country	Function	Range (km)	First Operational	Comments
Pave Way	U.S.	Air-dropped on surface targets	Free fall	1968	Homes on laser spot from designator
Sagger AT-3	SU	Antitank	3	1965	Optically sighted, wire guided
Grail SA-7	SU	Antiair	2	1972	Optically aimed, IR homing
CLGP cannon-launched guided projectile	U.S.	Guided howitzer	?	1980s	155-mm round homes on laser spot from designator
GBU-15 (developed from Modular Guided Glide Bomb)	U.S.	Air-to-surface	~ 110	Late 1970s	Winged 2000-lb bomb; changeable guidance module
HARM	U.S.	Air-to-surface	?	1980s	Homes on emitters (such as radars)
Condor AGM-53A	U.S.	Air-to-surface	110	Late 1970s	Can be remotely piloted by TV
Shaddock SS-N-3	SU	Surface-to-surface	400 to 900	1962	Launched against ships from surfaced submarines
Pershing II	U.S.	Surface-to-surface	730	1980s	Army nuclear ballistic missile made accurate with radar map matching
SLCM YBGM-109	U.S.	Surface-to-surface	550; 2380 to 3660	1980s	Low radar cross section cruise missile; radar homing versus ships, or terrain matching versus land targets
SS-NX-13	SU	Surface-to-surface	~ 730	?	Ballistic missile believed to have radar homing capability against ships

Table 2

ILLUSTRATIVE EXAMPLES OF U.S. REMOTELY PILOTED VEHICLES (RPVs)[a]

Vehicle	Designation	Function	First Operational	Comments
PGMs	Walleye II	Air-to-surface	1972	Guided bomb, TV picture remoted; steered through data link
	GBU-15 (developed from Modular Guided Glide Bomb)	Air-to-surface	Late 1970s	Winged 2000-lb bomb; one guidance option is remote piloting
	Aequare	Air-launched or ground-launched with rocket assist	Future	ARPA development for deep interdiction, using miniature aircraft with TV camera on board; explosive warhead option under study
	Condor AGM-53A	Air-to-surface	Late 1970s	TV picture remoted; normally antiship
Not PGMs	Aquila XMQM-105 (formerly Little-r)	Surface-to-surface	Late 1970s	Carries reconnaissance, laser designation devices; recoverable
	Compass Cope	Surface-to-surface	Late 1970s	Carries reconnaissance devices
	Praeire	Surface-to-surface	Future	ARPA development, using miniature aircraft with reconnaissance devices and laser designator
	Star	Shipboard-launched	Future	Carries reconnaissance, laser designation devices; recoverable

NOTE: Appropriate data on Soviet progress is not easy to set forth here. The Shaddock SS-N-3 and related cruise missiles may be used as RPVs at times; at least they are technically close to being RPVs.

[a]For a more complete list of U.S. RPV projects, see *Aviation Week & Space Technology*, March 17, 1975, pp. 93-94; and Government Marketing Service Publication GMS 74-9, September 1974.

than those used in the past; among other things, the consequent improvement in angular resolution makes guidance systems more accurate.

2. Continued development of microelectronic circuits (notably LSI--large-scale integrated circuits) that permit highly complex signal-processing and storage functions to take place in small, reliable, and relatively rugged devices.
3. The development of highly efficient warheads that have great destructive potential but are light in weight.

These technical developments, used in concert, have resulted in military hardware with capabilities unheard of in the recent past. For example, the development of practical airborne lasers that use frequencies so high--i.e., wavelengths so short--that they are typically just below the spectrum of visible light, has made it possible to guide weapons with angular accuracies approaching those of a high-powered rifle. When the signals reflected from a laser-generated spot that an individual has pointed at a target are processed by microelectronic circuitry, a very compact and effective guidance system can be used to steer a missile to within a few feet of a target from a launch distance on the order of 10 mi. It is just this combination that is being used in the new laser-guided Maverick antitank weapon system. But Maverick carries a very heavy warhead for its task, about 130 lb, and the whole round weighs about 460 lb. If the third development cited above, namely new efficient designs for high-explosive warheads, had been incorporated in the design, a missile with similar lethality, but significantly lighter weight, could have been built.

New types of RPVs (see Table 2), not many years from full-scale testing, will take advantage of new technologies to permit the construction of light and quite small vehicles by comparison with earlier-generation RPVs such as Condor. These systems, which could be launched from cargo-type aircraft, from the ground, from vehicles, or from ships, will have a remote operator who will continually monitor the performance and progress of the vehicle; detect, discriminate, and choose correct targets; and override the automatic guidance if necessary. The fact

that the vehicle is guided during its terminal phase makes it relatively insensitive to conditions at the time and place of launch, provided a data link can be maintained between the vehicle and its remote pilot.

The potential importance of some of these technological advances was brought dramatically to world attention[6] by their use during the late stages of U.S. involvement in Vietnam and during the Arab-Israeli War of October 1973. For example, in the last days of the war in Vietnam, laser-guided bombs having CEPs on the order of 10 to 20 ft were used, as compared with approximately 1000 ft for unguided bombs. This resulted, for certain targets, in an achieved target kill in two or three sorties, whereas 100 or more had been required for unguided bombs. The Arab-Israeli War of October 1973 provided many more examples of the operational implications of advanced weapons. There we saw how shaped-charge warheads made relatively small antitank weapons--notably, the Soviet Sagger missile and the unguided RPG-7 rocket--very lethal against Israeli tanks even though these weapons were quite small in size and were carried by individual Arab soldiers or mounted on relatively small vehicles. The shoulder-launched Grail heat-seeking antiaircraft missiles (SA-7) caused some changes in Israeli air tactics, while other elements of the Soviet-built mobile air defenses, such as the ZSU-23-4 radar-directed gun and the SA-6 heat-seeking missile, provided surprisingly (to the Israelis) effective air cover for the advancing Arab ground forces. Some of the weapons used in the October War were early models and underdesigned for their tasks; nonetheless, Israeli officers reported that their sheer numbers presented Israeli forces with an exceedingly

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[6] Note, however, that many of the *principles* of currently successful weapons have been around for many years. The Germans developed the wire-guided X-7 "Ruhrstahl" antitank missile in World War II and the French anticipated the Sagger and TOW missiles with their SS series of wire-guided antitank missiles. Wright Field engineers developed the AZON and RAZON steerable bombs, and these were used against bridges by the USAAF in 1944. Additionally, most of the air defense missiles produced since World War II have been steered all the way to their targets. What has changed in many cases is that new technical developments have permitted practical applications of the principles in the development and production of new weapons that perform much better than their anachronous predecessors.

dangerous threat.[7] These examples represent what might be the leading edge of a wave of quantum jumps in conventional weapon performance.

Two other important factors regarding these quantum jumps in performance are that (1) many of the new weapons are relatively inexpensive, and (2) many of them are relatively simple to operate. Note that we say *relatively* inexpensive and *relatively* simple to operate. Many of the new weapons are fairly sophisticated and can only be called inexpensive relative to manned systems or earlier guided missiles[8] or to the cost of the total number of other weapons that might be used to achieve an equivalent effect. Or they may be inexpensive relative to the target they are designed to kill. But they are not too expensive to preclude an abundant supply--and the possibility of abundance accounts for much of the significance of these newly produced weapons, as became clear in the Arab-Israeli War of October 1973. Thus the new technology has already been used in the mass production and mass use of precision-guided munitions that were simple enough to be operated by units that had little tradition of dealing with complex systems--albeit the Arab soldiers who used them were specially selected and highly trained.

QUANTUM JUMPS IN COSTS OF CERTAIN SYSTEMS

On the other side of the coin, many new and improved conventional weapons systems represent quantum jumps in cost. In each branch of the

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[7]There are also numerous examples on the Israeli side that highlight the pace at which new systems are now being introduced into military forces. Dr. Currie cites ten examples of systems that were not operational a decade earlier. Most of these were precision-guided air-to-ground weapons: Walleye, a 1967 TV-guided glide bomb; HOBOS, a 1968 electro-optically guided bomb; Maverick, a 1973 electro-optically guided weapon; Shrike, a 1964 antiradiation missile; and air-to-air weapons: AIM-9D and AIM-9G, 1964 and 1973 versions of the Sidewinder; AIM-7E-2, a 1964 version of the Sparrow; and Shafrir, a 1969 Israeli development based on Sidewinder. (From U.S. Senate, Hearings on S.920, Part 6, March 1975, cited on p. 2655.)

[8]Consider, for example, the YBGM-109 tactical cruise missile that has a target cost of $525,000 1975 dollars in contrast to the somewhat similar Bomarc air-defense missile that would cost about $2.3 million if 1955 dollars ($667,000) were converted to 1975 dollars. Bomarc, originally estimated to have a unit cost of only about $40,000 because of its "simple" ramjet engine and "simple" air-to-air radar seeker, was plagued with many problems besides underestimated costs.

military, several of the weapons systems whose development is given the highest priority are significantly more expensive than the existing systems they replace. This is especially so where weapons systems have multiple functions and are an integral, interwoven part of high-performance vehicles intended for use directly in the arena of combat. Consider a few such items in our catalog of conventional weapons: deep-penetration fighter-bombers, new tanks, and nuclear-powered aircraft carriers. The latest models of some of these weapons systems, although very capable, cost a great deal more than the systems they were designed to replace. For example, a single new nuclear-powered aircraft carrier costs about $1.5 billion as compared with a price tag of about 620 million 1975 dollars (or 310 million then-year dollars) for aircraft carriers in the mid-1960s. Whereas an F-4 cost about 10 million in 1975 dollars (5 million then-year dollars in 1965), the F-15 designed to replace it costs nearly $15 million. Indeed, as pointed out, a cursory look at the dominant features of some of our newest conventional weapons systems (a number of which fall into the category of improved replacements for aging weapons) suggests that many of these weapons are inexorably getting bigger, more sophisticated, more powerful, more provocative, and more expensive--without necessarily providing us with as great an edge over the Soviet Union as might result from more units of simpler design.[9]

These considerations are not made easier by the prospects that big, expensive systems may serve as a necessary platform for small, cheap systems. The GBU-15 glide bomb can be carried by an F-15, for example. The F-14 aircraft with a Phoenix air-to-air missile can be carried by a Kitty Hawk class (1961) carrier giving a considerable advance in capabilities. Such hybrid systems will be particularly necessary during the next 10 or 15 years.

Figures 1, 2, and 3 on the following pages indicate the consistency with which the cost of each of three basic kinds of military hardware

[9] "Simpler design" here means that the penetration into the combat area is done by the simplest possible weapons; often this means that they will be designed for the main expected circumstances, not for all conceivable ones. Their technical design would not be so advanced as to add greatly to initial cost or maintenance.

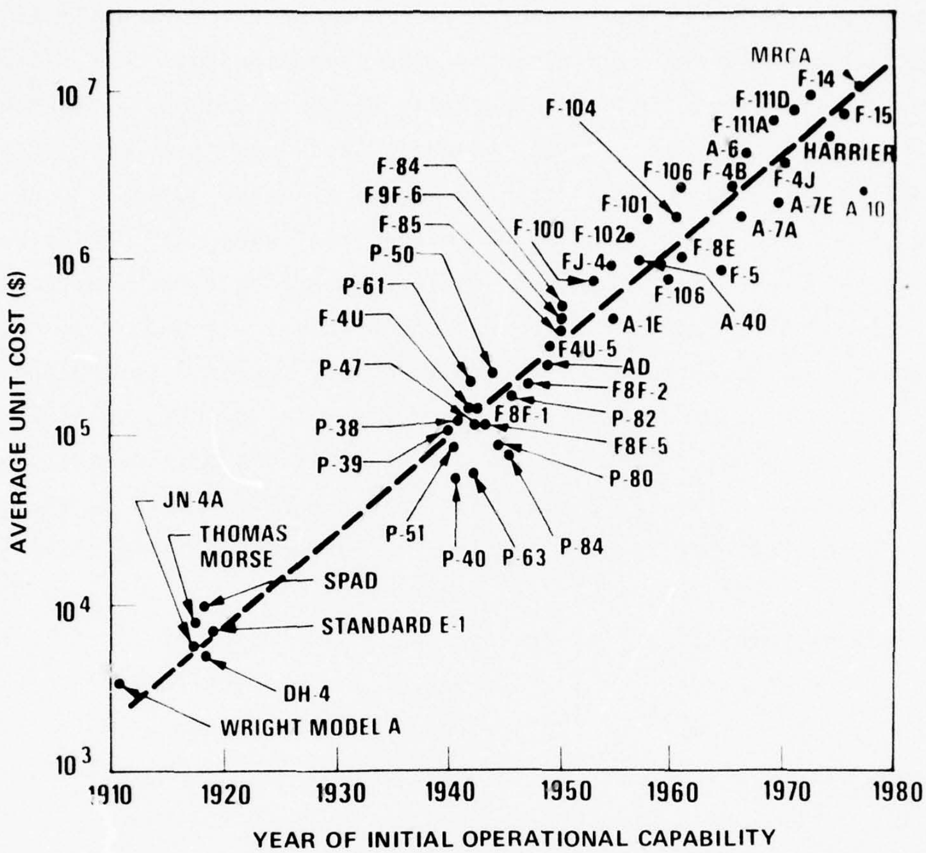

Fig. 1 — Unit cost increase with time — Tactical Aircraft

has risen in recent decades.[10] (Note that the ordinate in each figure is a logarithmic scale.) With regard to these figures, Augustine comments that

> The unit cost of major items of military hardware has been increasing at a significantly faster pace than the DoD budget itself or, for that matter, the Gross National Product.... [If the trends continue] we will reach a point in the year 2036 where the Defense Department will literally be able to afford only one aircraft. [p. 34]

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[10] Figures 1, 2, and 3 are taken from Norman R. Augustine, "One Plane, One Tank, One Ship: Trend for the Future?" *Defense Management Journal*, Vol. 11, No. 2, April 1975, pp. 34-40. Augustine, now Under Secretary of the Army, does not specify that the costs in each of these figures are "then-year" procurement costs but presumably they are. We have corrected an apparent error in the ordinate of Fig. 3 by multiplying the *Journal* figures by 10.

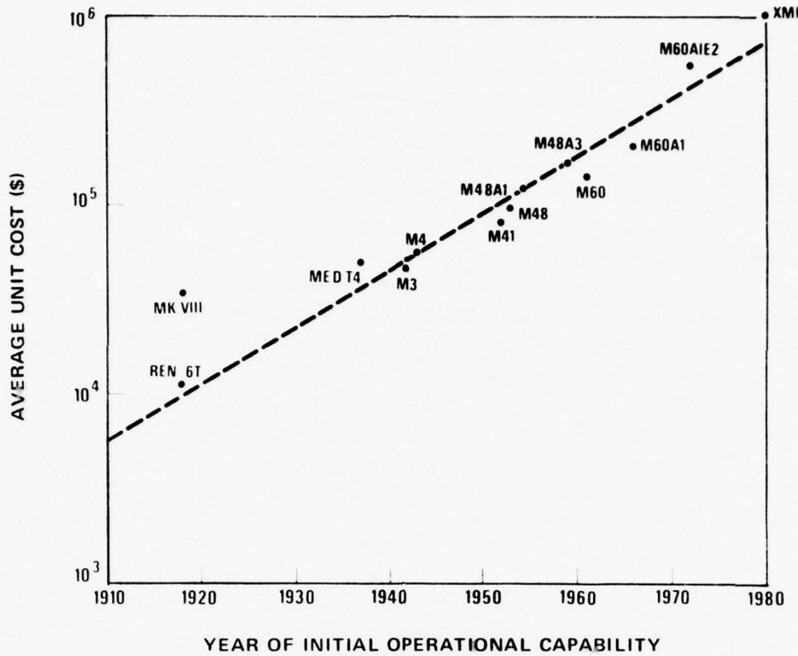

Fig. 2 — Unit cost increase with time — Tanks

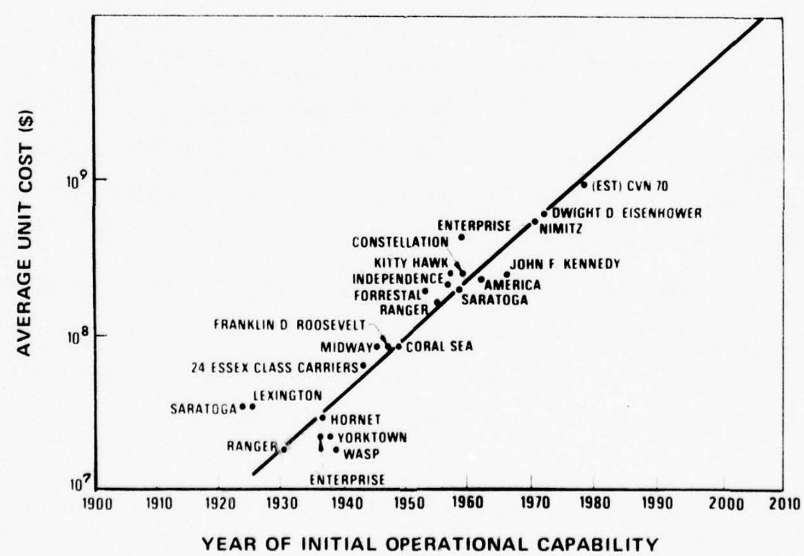

Fig. 3 — Unit cost increase with time — Aircraft Carriers

He then concludes his article with

> <u>A Glimpse at the Future</u>
>
> It is inevitable that the past trend in rising equipment costs must decelerate and that numerical sufficiency cannot indefinitely continue to play a secondary role in qualitative superiority. Nonetheless, selective qualitative gains remain an essential goal, with especially high leverage being achieved through research and development dedicated to the reduction of manpower and other support demands with the efficiencies thereby realized being transformed into additional fighting elements. Thus, in the years ahead, we could profitably shift the focus of our R&D from near-total concentration on increasing performance to a more balanced attack which includes, as one element, a major assault on support costs. [p. 40]

Calculations of cost and effectiveness that compare the value of different weapons systems are exceedingly difficult and, at best, subject to many qualifications and arbitrary assumptions. There are, of course, experts who state a very impressive case in favor of each of the complex systems up for decision; these are a main feature of service testimony at Congressional hearings. On the other side, three opposing arguments seem relevant:

(1) In the Brookings Institution review of the FY 76 budget, it is pointed out that a nuclear-powered aircraft carrier costs about 50 percent more than a comparable conventionally propelled carrier; thus three conventionally powered carriers can be acquired for the price of two comparable nuclear-powered vessels.[11]

(2) In his recent book *On Watch*,[12] Admiral Elmo P. Zumwalt said that a patrol frigate can perform certain missions as well as a nuclear-powered cruiser. But for the price of one nuclear-powered cruiser, the United States could buy five patrol frigates.

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[11] Barry Blechman, Edward Gramlich, and Robert Hartmann, *Setting National Priorities: The 1976 Budget*, The Brookings Institution, Washington, D.C., 1975, pp. 107-108. The costs referred to there include only construction cost plus 30-year fuel cost. Full system cost comparisons are more complicated.

[12] Quadrangle/The New York Times Book Company, New York, 1976, p. 102.

(3) Dr. Richard L. Garwin, an IBM Fellow at the Thomas J. Watson Research Center and consultant to the Department of Defense, was quoted in *Forbes* (April 15, 1975, p. 23) as saying that "While the F-15 can beat the improved MiG-21 on a one-to-one basis, an equal-cost force of MiGs would just eat up the F-15 because the advantage of numbers is so great." The same article estimated that the price of one F-15 would buy seven MiGs in the United States. (This statement--which may not quote Garwin in full--is more interesting as an example of perceptions than as analysis, since it evidently ignores operating costs and compares the F-15 with a MiG of unspecified vintage without saying anything about types of armament.)

Thus, for the foreseeable future, a major dilemma for the United States will be the need to reconcile demands brought on by a changing and numerically impressive threat with pressures for nonmilitary programs, while allocating military funds between expensive systems in smaller quantities and cheaper systems in larger quantities.

INCREASED IMPORTANCE OF THE SUPPORTING STRUCTURE

For the new precision weapons, the supporting structure in which they are used may be crucial to their success in a large-scale war. The control over this structure has some major implications for arms limitations and for big-power control over arms transferred to smaller powers. Yet it is commonly overlooked as analysts describe the great improvements approaching "one shot, one kill" that might apply in one-on-one engagements. In a large-scale conflict, the characteristics of individual weapons, taken one-on-one, could be dominated by the way thousands of weapons of several types are made to work together in a mutually supportive way.

This supporting structure has several elements: (1) the advance reconnaissance that localizes targets, (2) the target acquisition system that identifies individual targets right up to trigger-pull, (3) the command function that allocates and marshals the new weapons to the place where they are needed most, (4) the combined-arms partnership that protects the crews of the new weapons while they do their jobs, (5) the transport (perhaps laterally to a front) of the new lightweight but powerful weapons systems, and--most important--(6) the network that replenishes expended weapons.

The importance of this supporting structure can be appreciated when one considers that a brigade commander in World War II might do his job from a situation map that showed where six enemy motorized rifle battalions and three tank companies were located. In 1980, he and his staff might need to keep track of 500 to 1000 individually moving and independently powerful squad-size units. To fully exploit his PGMs, each of these targets would have to be acquired on an individual basis.[13]

For a large-scale war, along NATO's Central Front, for example, or along the Sino-Soviet border, the decisive aspect might turn out to be the battle to destroy the enemy's supporting structure. Thus each of the six elements named will need to be as invulnerable (or nondisruptable) as possible. For instance, U.S. air commanders would need to ensure that replenishment supplies of Maverick missiles (or their successor) would continue to arrive at loading points during battle, and that the quantities on hand and pathways for resupply were designed to hold up under the attacks that would undoubtedly be pressed against them.

For a small-scale war, where the numbers of targets presented per day were in the tens rather than thousands, the single-shot kill probability or one-on-one weapon performance might be the dominant factor. But there is an intermediate case of considerable interest in connection with the consequences of arms transfers to the nonindustrial countries, where recipients might acquire hundreds of the weapons themselves, but not be capable of dealing with all elements of the supporting structure. Another war in the Middle East might well be of this intermediate size. As a part of U.S. policy on arms transfers to the Middle East, it is important to think through the extent to which our government could exercise some continuing control over the large-scale employment of these arms, such as by controlling reconnaissance or replenishment functions essential to the full exploitation of the weapons.

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[13] Some senior American officers, having sized up this situation, are now calling on the research and development community to improve non-nuclear weapons with area coverage. This is of considerable importance with respect to arms limitations, since it might make constraints on weapons employment designed to reduce collateral damage more difficult.

IMPORTANCE OF INCREASING MANPOWER COSTS

Despite order-of-magnitude increases in costs of some weapon systems, that portion of the DoD budget devoted to procurement of military equipment has been steadily shrinking. In 1955, 41 percent of the defense budget--$14 billion--was spent for aircraft, ships, tanks, and other military hardware. Twenty years later, in 1975, the absolute amount was almost the same--$14.8 billion--but procurement of these items accounted for only 18 percent of defense spending. During that same period the cost of military personnel increased from $10.6 billion to $25 billion even though the number of persons in service decreased from 3.2 million to 2.2 million. Put another way, the average annual cost per person in the armed forces increased from $3350 in 1955 to $11,500 in 1975, with the greatest rate of increase occurring after 1970 as a result of the transition to an all-volunteer force.

The Soviet Union maintains active armed forces almost twice as large as those of the United States--4.2 million men and women, of whom about 2 million are conscripts. No matter how poorly paid a Soviet conscript may be, the forces are large, and although Soviet authorities may not be as strongly motivated to conserve human resources as their American counterparts, they cannot be indifferent to the opportunity costs of devoting so much manpower to the military.

High manpower costs have several implications for force planning. In some cases, by spending more on equipment, total costs could be reduced by increasing the productivity of each man. For support units that may imply the introduction of labor-saving machinery. For combat units it means procuring more accurate and more lethal weapons to increase firepower while holding manpower constant. It may also imply designing new equipment to reduce manpower requirements throughout its entire life-cycle. Perhaps crew size could be reduced, or higher reliability could be designed into the equipment so that fewer maintenance personnel would be required.

More relevant to the present discussion is the possibility that investment in one relatively expensive guided missile may eliminate the need for several hundred iron bombs or artillery shells and the manpower and overhead expenses involved in transporting, handling, storing, and

loading them. A decline in the need for support personnel should have a beneficial effect on teeth-to-tail ratios, particularly in the ground forces. Thus, one could envisage an increase in the number of combat units with no increase in military personnel or manpower-associated costs.

Adding a new combat unit does imply a substantial investment. A U.S. armored division force equivalent (the division and all combat, combat support, and combat service support units required within a theater of operation to conduct combat operations) has a nonrecurring cost, excluding RDT&E, of approximately $1 billion. This cost is for initial procurement of equipment, supplies, and spare parts but not missiles or ammunition. The annual recurring cost is about $600 million of which perhaps 75 percent is for military personnel. Increasing the annual outlay for ammunition and missiles (about $30 million) by a factor of two would increase recurring costs by about 5 percent. Thus, even without possible savings in manpower, the incremental cost attributed to equipping the division with the latest in conventional munitions would not be great--though it might come from tight budget categories.

These are factors that must be borne in mind in considering how qualitative constraints might impact on force structures, since it seems clear that the United States cannot afford to be handicapped, particularly in attempting to maintain the balance in Europe, by foreclosing ways that might make each man count for more.

III. IMPLICATIONS OF THE NEW TECHNOLOGY OF PRECISION GUIDANCE

The recent and rapid technological developments indicated in the previous sections have resulted in a variety of new weapons systems that are quite precise--both in hitting intended targets and in avoiding unintended targets. Many are quite efficient in terms of kills per pound or kills per dollar when operated under ideal conditions. But conditions are not always just right, and this section on their implications treats them not only at their best, but also mentions the possibilities of poor performance. We discuss, below, the implications of precision-guided munitions (PGMs) and remotely piloted vehicles (RPVs) by expanding on eight summary points.

1. *Many PGMs and RPVs appear to represent a quantum jump in military effectiveness (even when compared with quite expensive alternative systems that do not use precision guidance). However, there are some situations in which their effectiveness is limited--and those should be faced squarely.*

Perhaps the great advantage of PGMs--if they are used under the conditions for which they were designed--is best summarized in the following statement:

> Accuracy is no longer a strong function of range; if a target can be acquired and followed during the required aiming process, it can usually be hit. For many targets hitting is equivalent to destroying.[1]

Notice, though, that even this brief statement implies that a number of things can go wrong. For one, the process of target acquisition may not be easy. Even for targets that are acquired, it may be difficult to track the target with presently deployed equipments, most of which

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[1] Slightly modified from James Digby's *Precision-Guided Weapons*, Adelphi Paper No. 118, The International Institute for Strategic Studies (London), Summer 1975, p. 4.

are visual or near-visual wavelengths. Bad weather, battlefield smoke, camouflage, or other obscurants may prevent tracking at any but very short ranges. In some cases, efficient employment depends on a good command-control system, and some current systems are better known for their deficiencies than for their excellence. Countermeasures can also be taken against the PGM or its crew--some technical in nature and some tactical, such as evasion by the target during the missile's flight or attacks on the PGM crew while it is trying to guide the missile. These targeting and environmental difficulties, which can be particularly severe for long-range PGMs and RPVs, must be overcome before these weapons can be usefully employed in a wide variety of operating conditions. In some cases, this may be accomplished through technological improvements in the supporting structure or by redesigning tactics to exploit them effectively; in others, it may be more difficult.

In spite of these difficulties, in many situations PGMs and RPVs will perform well enough to make a major difference.

2. *Many PGMs and RPVs are relatively cheap--cheap to develop, to procure, and to operate. But to understand the full cost implications, some context is needed.*

As is shown in the selected examples of PGMs and RPVs in Table 3, the new weapons range in cost from under \$5000 for antitank missiles such as TOW to an estimated cost of over \$500,000 for a long-range cruise missile. Those costs may seem high compared with the cost of an artillery round (\$100) or a 2000-lb iron bomb (\$1000), but they are low relative to the cost of their targets. The latest version of the M-60 tank costs almost \$600,000; almost any kind of a capital ship costs over \$100 million; and a nuclear carrier fully equipped with 90 aircraft represents an investment of over \$2 billion. Thus the force-wide cost of adding PGMs can appear high or low, depending on how many must be bought for each expected kill, and the usual cost comparisons are apt to be misleading unless they are placed in an operational context.

Table 3

ILLUSTRATIVE PGM AND RPV COSTS[a]

Weapon	Unit Cost[b] (1975 $)	Production Quantity
TOW	4,000	150,000
Dragon	5,000	80,000
Maverick (TV)	22,000	30,000
Sidewinder (AIM-9L)	37,300	1,800
Condor	333,000	162
Harpoon	436,000	785
SLCM (strategic)	525,000 (est.)	---

[a]For a discussion of missile costs in general, see Appendix A.

[b]Costs of fire-control systems and launchers are not included except for Dragon.

Most PGMs used under the conditions for which they were designed have higher kill probabilities than the unguided weapons they replace.[2] Under good conditions, one Maverick is clearly more likely to hit and destroy a target than one iron bomb, but whether one Maverick does the job of 10, 50, or 1000 iron bombs depends on the tactical situation--the effectiveness of the defenses, weather conditions, time of day and sun angle, pilot skill, and a number of other factors. Consequently, while Maverick may be cheaper than the number of bombs required in one situation, it may be more expensive in another, and may not be usable at all in some situations.

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[2]To date, most PGMs have been designed to attack point targets (individual tanks, ships, aircraft, bridges, etc.), and our discussion of cost-effectiveness generally relates to point targets. This is not to say that some types of precision-guided weapons would not be useful against area-type targets; Rockeye and the German weapon Strebo are examples of PGMs designed especially for such targets. Other PGMs for area-type targets are likely to be designed in the future. In any case, since many battlefield targets are of the area type (e.g., troop concentrations, vehicles on the move or parked, and repair facilities), there will continue to be a need for weapons appropriate for these types of targets, both PGMs and non-PGMs.

Assuming for the moment, however, that for certain circumstances one could estimate that one Maverick at $22,000 is equal to 50 2000-lb bombs at a total cost of $50,000, he would still not have a valid comparison. In both cases, the costs that dominate are those of the aircraft, aircrew, airbase, logistics structure, and training establishments needed to ensure that the weapon is delivered. Moreover, in most situations the Air Force has felt the need to send along a number of supporting aircraft with the PGM carriers to aid in defense suppression. The real savings would come from the reduction in sorties required to destroy the target. One sortie with four Mavericks plus four supporting sorties, compared with 60 sorties with unguided bombs, means reductions in crew losses, aircraft attrition, fuel, maintenance, support, and training. Thus a comprehensive fixed-effectiveness cost comparison would favor PCMs decisively in those situations favorable to their use. But if the weather were bad, but not so bad that it would ground all aircraft, Maverick might not work at all, and this would have to be taken into account statistically and by keeping backup systems.

At the high-cost end of the spectrum in Table 3 are such highly sophisticated weapons as the Condor and the sea-launched cruise missile (SLCM), which have both high-development and high-production costs. The SLCM, for example (in both tactical and strategic versions), is now estimated to cost almost $1 billion for RDT&E, and over $500,000 per unit in production. Would this be an excessive price for a missile capable of finding and destroying a surface ship at a range of up to 2000 mi? When one considers the value of a ship relative to the SLCM, the tradeoff appears advantageous to the PGM even if several had to be fired. But a more complete analysis would require an examination of alternative ways to do the same job. For example, what would be the comparable cost if airplanes with unguided weapons were used?

Whether widespread deployment of PGMs would actually result in net cost savings is a different question. Force planners may operate on a fixed-cost basis (i.e., fixed procurement budget) rather than on a fixed-effectiveness basis, and effectiveness would increase as expenditures remained constant. Net costs are found by considering unit costs, such as those in Table 3, in the context of a force structure. To do

this, more complex cost consequences must be considered, including whether one must have expensive supporting activities and accompanying forces (as mentioned above for Maverick) or backup forces for cases in which PGMs do not work well. Nonetheless, the evidence points to substantial efficiencies where PGMs can be fully exploited.

3. *Many of these new weapons could be developed and manufactured using existing facilities and current production methods. Others, which may be very useful, require advanced industrial facilities.*

Consider first the laser-guided bomb (LGB); it requires only a pulsed laser designator, with a simple quadrant detector and a "bang-bang" control system on the bomb.[3] This equipment is all quite easy to develop and manufacture. It undoubtedly could be or has been built in the Soviet Union, and is probably within the capabilities of several Third World countries as well. Another example of a precision-guided weapon that has already been widely developed and manufactured in several versions is the semiautomatic wire-guided missile. The rocket motor technology and the techniques for unreeling the wires (that carry the guidance signals) out the rear of the missile were developed by the Germans during World War II. The tracking and guidance system typically uses inexpensive flares or light beacons on the missile as infrared sources. Both the infrared tracker (located at or near the launcher) that follows these beacons and sends guidance signals to the missile, and the missile system itself, can be easily fabricated using what is now standard technology.[4] Furthermore, the development and manufacture

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[3]This is a simple silicon detector that measures the laser energy reflected from the target in each of its four quadrants and sends steering signals to the fins on the bomb to keep the laser spot centered in the detector, and thus keep the bomb directed toward the target. The control system has only two positions for each fin, thus the term "bang-bang."

[4]In a typical design, the infrared tracker employs an optical encoding reticle, infrared detectors made from silicon or germanium, electronic amplifiers, and decoding circuitry. Depending on the instantaneous position of the target on the reticle, the infrared detector

of both of these types of weapons can be accomplished in laboratories and factories that are externally indistinguishable from a television factory.

On the other hand, some of the other new weapons are rather difficult to develop and manufacture: some require a high degree of technology and some require special manufacturing techniques. An example is IR Maverick (which can be used at night and in limited-weather attacks against targets such as tanks, trucks, and APCs). This new weapon system uses high-technology forward-looking infrared (FLIR) sensors for target acquisition, and takes advantage of new trimetal (HgCdTe) detector technology in the imaging infrared guidance unit in the missile itself.[5]

It seems clear that the United States holds the lead, at least for the moment, in many of these new technologies that have great possibilities for increasing military capabilities. For example, it is doubtful if the Soviets have yet developed high-quality FLIR sensors. Moreover, it should be remembered that the new technologies have no military worth in themselves. It is only when they have been engineered into military

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develops signals that indicate the displacement of the target from the missile flight path; these signals are then sent to the missile through the wires to keep it on target. Such a system can be operated from the ground, or from a carrier such as a tank, a weapons carrier, a jeep, or even from a helicopter.

[5]HgCdTe detectors have largely replaced doped germanium detectors for application in FLIR sensors, primarily because they require less cooling, liquid nitrogen temperatures being adequate. They also have a much higher infrared absorption coefficient, and so may be made much thinner; correspondingly, they have larger quantum efficiencies. Their impedance is low, and response time is in the microsecond to nanosecond region. The fabrication of these detectors, together with the associated preamplifiers, particularly in the high-density arrays required for FLIR sensors, requires, however, very specialized technology. This technology involves, among other things, advanced photolithographic techniques; it has evolved over the past several years at a few industrial laboratories in the United States; it is highly competitive and protected by tight industrial security. The problems are aggravated in the missile application because of strict cost limitations. (See R. B. Emmons, S. R. Hawkins, and K. F. Cuff, "Infrared Detectors: An Overview," *Optical Engineering*, Vol. 14, No. 1, January/February 1975, pp. 21-30; and H. Levinstein and J. Mudar, "Infrared Detectors in Remote Sensing," *Proceedings of the IEEE*, Vol. 63, No. 1, January 1975, pp. 6-14.)

hardware which can be mass produced that their full potential can be realized.

Thus, a major consideration affecting decisions regarding qualitative constraints is the degree to which the capabilities of the United States (and the rest of the industrialized Western world) to mass-produce large quantities of high-technology weapons (at relatively low cost) can be relied on to help offset the quantitative superiority of the Warsaw Pact forces.

4. *There may be important consequences for logistics deriving from the small size but great effectiveness of the new weapons.*

Many of these new weapons tend to be both small and effective in comparison with (a) the target they are designed to attack, (b) the systems they replace, or (c) much larger and more expensive unguided weapons.

For example, the TOW missile is 15 cm in diameter, 117 cm long, and weighs 23.6 Kg including its protective container, which serves as a launch tube. The warhead itself, a shaped-charge design, weighs only 3.6 Kg. Yet this missile can destroy or disable a modern tank many times its size, and weighing more than 60 tons, at ranges up to 3750 m. Functionally, this missile, with its launcher, replaces the much bulkier and usually less-effective 106-mm recoilless rifle. Similarly, a Stinger surface-to-air shoulder-fired missile that is less than 10 cm in diameter, 152 cm long, and weighs 13.4 Kg can destroy a fighter aircraft flying within its speed and range envelopes--a job that normally would have required many rounds of antiaircraft gunfire.

In the case of a longer-range weapon, the Navy's YBGM-109 sea-launched cruise missile is designed to be launched from standard-sized torpedo tubes (as well as from A-6's or ships). It is likely that the "tactical" SLCM will be able to disable or destroy a variety of major surface combatants, and that the "strategic" SLCM will be able to attack a variety of high-value on-shore targets, such as power plants, bridges, and POL facilities at ranges of 1400 mi or more. In performing these

tasks, its predecessor was the A-6 aircraft armed with nonprecision weapons, and the platform was a CVN instead of an SSN or frigate.

Because many of these new weapons are small in size and high in effectiveness, there is the possibility that the weight and volume of munitions that will have to be hauled to the battle area to accomplish a given task will be considerably less. This would have a major effect on the logistics of replenishment (although the probability of much-increased consumption rates needs to be factored in). For example, for air-delivered weapons, if sorties can be cut, then so can the number of aircraft required, together with maintenance and associated supplies. This "ripple effect" could thus magnify by severalfold the reduction at the cutting edge: Not only are there savings in direct support for the weapons and their crews, but additional savings accumulate at each echelon as the support units themselves shrink and, in turn, need less support from units farther back. This ripple effect needs to be carefully studied, partly because the prospect of higher consumption rates for a shorter time means a quite different logistics design, and partly because the logistics system may be a prime target itself. But there still may be a net savings even after the costs incurred by the added personnel required for PGM and RPV maintenance and supply have been taken into account.

5. *Many of the new types of weapons can be moved quickly and in quantity to the places where they are needed most.*

Because of their small size and light weight, many of these new weapons could be moved to defend an area where an offensive threat was developing. This, of course, would require that necessary transport be available, together with tactics to exploit the combination. For example, antitank weapons such as TOW and Dragon and antiaircraft weapons such as Stinger could be transported quickly and in quantity by helicopter or small aircraft to a threatened point where an armor and air attack was developing; some army planners also talk of transporting a lightweight vehicle (such as the XR-311 Dune Buggy) to carry them into combat. By contrast, this would not be possible for tanks.

It would be necessary to develop new tactics for this kind of use, since they would differ considerably from those used in traditional defenses against tanks. The attacker's tactics would also quite likely be modified both to exploit his PGMs and to defend against opposing PGMs. Thus while these complications plus some others involving command structure and reliable communications would have to be overcome, the possibility of getting a larger quantity of more effective defensive missiles into the action should be very helpful along NATO's Central Front, given the numerical imbalance there.

6. *Many of the new PGMs and RPVs are particularly useful to a defender.*

It is quite complicated to discuss whether a given weapon is advantageous to the "defense" in contrast to the "offense." Along a wide front, an offensive involves defensive holding over most of its length. Especially when forces have mostly short-range PGMs, the success of an offensive move will depend on being able to defend a vantage point once it is taken. However, several things can be said about the defensive value of the new-generation weapons. First of all, most currently available PGMs are specifically designed to be primarily defensive. This includes antitank and antiaircraft guided missiles. Second, target acquisition is the key to successful use of most of these weapons, and it is much easier for a defender to remain concealed than it is for the attacker, who is moving through (or flying over) unfamiliar territory, and who has no opportunity to prepare positions. The very nature of this kind of warfare makes concealment extremely important.

It will probably be easier to conceal relatively small units--perhaps as small as a three- or four-man individually mobile squad. With PGMs, such small units can represent a great deal of firepower. Moreover, the act of concentrating forces, classically so necessary for an offensive thrust, would be likely to attract the attention of reconnaissance systems. This may make such thrusts harder to bring off, because once the concentrated forces are spotted and tracked, great numbers of PGMs and RPVs might be brought to bear on the thrust.

7. *Even the largest PGMs and RPVs (e.g., the sea-launched cruise missile) can be hard to detect and their carriers can be effectively disguised. They can be launched from a wide variety of platforms without affecting terminal accuracy.*

A consequence of the concealment possibilities will be the need for better reconnaissance systems and for real-time fusion of intelligence from many sources. During peacetime, security requirements have been allowed to block effective, fast transfer of some kinds of intelligence. This may have to be changed because of the threat presented by concealable PGMs and RPVs. A second consequence--of great importance to the monitoring of nuclear as well as nonnuclear agreements--is that "national means of verification" just will not be adequate a decade from now. Finally, from the last part of the statement, one can expect that weapons systems and launch platforms will increasingly be treated as independent designs, independently developed and procured. When a transport aircraft or cargo vessel may carry either cargo or operational missiles or both, changes in tactics are likely.

8. *There are important political consequences stemming from the new weapons.*

Perhaps the most important political consequence is the possibility of lowering the damage to nonmilitary targets. Since the new missiles can be made to be quite precise, they can disable their intended target without damaging nearby civilian installations; civilian casualties can thus be minimized.[6] This opens up the opportunity for agreements, or implicit understandings, that would strictly limit civilian damage in a conventional conflict. Abiding by such an undertaking may be an efficient way for military forces to operate, as they did for hundreds of years, as well as being morally attractive and mutually beneficial to both adversaries.

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[6]This effect, however, is mitigated by the constantly and rapidly increasing urbanization of the developed countries, which leads to the colocation of many military targets with civilian communities.

Precision is particularly important in a nonnuclear conflict between the superpowers, since one of the most crucial aspects of such fighting is the signal content of the actions undertaken, i.e., what these actions mean in terms of willingness to escalate or conciliate. In other words, the military commander could offer to the political leadership a number of options. One of these could be selected to fit the tone and intent of the political discourse. (For example, a submarine base could be attacked if it had supported raiders who had torpedoed friendly ships.) The objective would be to get the opponent to cease his actions. But this matching of target to objective would be obscured if substantial unintended damage occurred, in which case an unwanted widening of the conflict might occur.[7]

A second political consequence is that the deployment of very effective nonnuclear weapons can reduce the necessity for using nuclear weapons in certain cases, thus raising the nuclear threshold. This is not to say that nuclear weapons would not be much more effective against some targets. But precision guidance greatly increases the set of targets that can be dealt with effectively with nonnuclear weapons, and there will be less need to compensate for inaccurate delivery by increasing the warhead's lethal radius. Nor does this say that the Soviets will see the choice between staying with high explosives and "going nuclear" in terms of Western-style calculations.

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[7]Note that a posture that includes a strong and flexible conventional capability signals *in advance* an intent to try to settle matters without resorting to nuclear weapons. But it need not convey certainty that they would not be brought to bear at some stage, especially if nuclear pre-emption were suspected.

PART THREE: APPROACHES TO ANALYSIS

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IV. ANALYTIC ASPECTS OF DECISIONS ABOUT QUALITATIVE CONSTRAINTS

Decisions about qualitative constraints will depend on the answers to questions at several levels: (1) What are candidate systems for agreement or understanding? (2) What are the incentives for the United States (and for the Soviet Union) for a particular agreement? (3) Do qualitative constraints seem useful to pursue as a general class? In practice, most decisions will probably be approached heuristically--that is, an official or an analyst will come up with a hypothesis that a certain set of constraints seems promising in terms of arms control objectives. Then this hypothesis will need to be tested (and retested) so that decisionmakers can evaluate its implications and understand them sufficiently well to help shape proposals for constraints.

By and large, the above questions can be addressed in terms of three criteria: desirability, feasibility, and acceptability.[1] Because an understanding of these criteria is crucial to any assessment of arms control options, we will begin this section with a general discussion of qualitative constraints in terms of these criteria, and then describe three ways of testing hypotheses analytically.

DESIRABILITY, FEASIBILITY, AND ACCEPTABILITY

In brief, desirability refers to an objective and analytical evaluation of the net incentives for agreement, whereas acceptability refers to whether or not the agreement is politically palatable. Feasibility refers to the ability to monitor, inspect, and ensure compliance with the agreed-upon terms. As Amrom Katz has already pointed out, the technical and political problems are inextricably mixed, so it is necessary to consider them simultaneously. But one must talk about them (or analyze them) sequentially.[2]

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[1]This treatment factors the criteria into three headings rather than the two of the classic treatment by Amrom Katz in "Feasibility and Palatability of Disarmament," *Disarmament*, No. 7, September 1965, pp. 1-6.

[2]Ibid., p. 1.

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Desirability

The desirability of qualitative constraints inheres in the advantages and disadvantages accruing to the potential parties to any international agreement limiting qualitative improvements. To assess the desirability of possible agreements, one must identify those interests of potential participants that could be served better by imposing qualitative constraints than by continuing the competition in qualitative improvements.[3] The first steps in an assessment of desirability are to identify and analyze those interests as well as the potential benefits to each side, such as, for example, cost savings and improved stability. Judgments about the desirability of hypothesized qualitative constraints will depend on what assumptions are made about the implications of new technology and on the specific uses ascribed to the weapons constrained.

Feasibility

The criterion of feasibility includes some important mechanics of an agreement: can compliance be verified, violations detected, and the agreement enforced? In short, can the agreement be made to work? Among other things, this will depend on

1. The identification of *points of control* in the weapons development, testing, and acquisition process.
2. The identification of *measures of control* that effectively exploit those points of control in placing constraints on particular qualitative advances.
3. The availability of *verification* procedures by which effective execution of control measures can be determined.

Thus, a limitation on new aircraft systems will be deemed feasible if critical phases of, for example, the R&D, testing, procurement, or development stages can be found that could be affected by certain control measures whose implementation can be verified, and where results

[3] Here we intend a "qualitative change" to include bigger, more all-purpose weapons, as well as those using new technology.

can be observed through inspections, reconnaissance, or other intelligence sources; through budgetary accounting; etc. It is also necessary that such a limitation be enforceable against attempted breach of the agreement (through available sanctions).

Points of control might be found by identifying (a) critical characteristics of weapons systems, or advances in them, that may be subject to effective limitation, and (b) phases within the weapons acquisition process that are most subject to controls. For example, in the United States there are five well-defined phases in the acquisition process of a major defense system: the conceptual phase, the validation phase, the full-scale development phase, the production phase, and the deployment phase.[4] Weapons in the earlier phases are generally harder to catch, but easier to stop; those in the later phases are easier to catch, but more difficult to stop. To determine more precisely where and when, in the weapons development process, controls could be effectively imposed, one must draw more precise distinctions between phases, as defined by the kinds of operations involved, the nature of the inputs (resources required), and the final products of those operations. We would expect to find that different weapons systems and technological research would be subject to varying degrees of control--especially verifiable control--at different phases of the weapons acquisition process.

Measures of control might include broad, generalized steps to limit qualitative advances overall, steps to limit particular qualitative advances, or steps to limit other military inputs that are necessary to exploit fully the availability of new technology. Such measures might include:

- The use of limitations on military expenditures to encourage reductions in qualitative improvement and procurement.
- Bans or limitations on development, testing, production, and deployment of the weapons.

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[4] See Hq USAF Pamphlet 80-10, February 12, 1974, Department of the Air Force, Headquarters United States Air Force, Washington, D.C., 20330.

- Stretch-out in the introduction of new types of weapon systems.
- Limitations on logistic support systems for certain weapons.
- Limitations on deployments abroad.
- Quantitative limits on certain systems whose value is increased by new technology or by new systems.

Verification of adherence to control measures on qualitative improvements is the most difficult problem. Desirable verification measures would satisfy the following conditions:

1. The verification methods must produce unambiguous and credible evidence of breaches of the agreement.
2. The evidence should be visible at the earliest possible stage of development of new or improved weapons systems.
3. The evidence of breach of the agreement should be linked to credible threats of sanctions.
4. Self-enforcing mechanisms are probably to be preferred, if, in fact, they are practicable.

This last point may be quite important in reaching any future conventional arms control agreement. Effective verification of the performance of control measures on R&D, for example, may require techniques far too obtrusive for potential parties to an agreement to accept. Reliable self-control mechanisms might reduce the need for continuous and direct verification by external parties.

With such self-enforcing mechanisms, not only must methods of controlling qualitative advances provide reliable information to other parties to an agreement, but that information must be unambiguous and credible to a wider political audience. That is, a condition for sanctions would be incontrovertible evidence that a breach of the agreement had occurred. Surreptitiously gained information, with its source unidentified and its reliability otherwise unverifiable, may not be sufficient to convince relevant groups of the need for sanctions or a counterbreach of the agreement.

Acceptability

Although certain forms of qualitative agreements may be both desirable and feasible, this does not guarantee that specific terms acceptable to the nations involved can be formulated. Important considerations affecting the acceptability of specific agreement terms include the budgetary impact of the agreed-upon constraints, as well as their implications for

- Domestic economic and political affairs.
- Internal security aspects of verification measures.
- International monetary positions.
- Arms transfer clients.
- National prestige.
- Relations with allies.
- Stability of arms competitions.

Each of these considerations raises a number of questions. Will qualitative constraints prevent cost-effective substitutions of technology for costly resource inputs such as manpower? Are there inefficient resource allocations now in practice in the Soviet Union--such as continued high investment in air defense--that the United States would prefer to have continued? These budgetary considerations are closely linked to some political considerations related to the acceptability of qualitative arms constraint agreements. For example, will the terms of an agreement adversely affect the interests of important bureaucratic-political groups, such as the military services? Important economic interest groups might also be adversely affected. For example, the aircraft production industry in the United States has been dependent, both for its general economic health and for technological developments, on the continuation of R&D on new military aircraft.

Verification procedures loom all-important in evaluating acceptability. They present a different order of difficulty in comparison with the other considerations mentioned above in that in many cases verification may require obtrusive techniques, such as on-site inspection or special reconnaissance, which are highly unlikely to be acceptable to both sides in a U.S.-Soviet agreement.

Analytically, the criterion of acceptability is more elusive than desirability or feasibility. Judgments regarding desirability and feasibility can often be based on quantitative information or at least can be stated in terms of well-defined concepts clearly understandable by all. For example, program life-cycle cost, which may be a factor in evaluating desirability, can be stated quantitatively; and detectability (e.g., by a surveillance satellite), used to evaluate feasibility, can be specified in terms of the minimum-size object that is resolvable by a satellite-borne optical system. Or, as already mentioned, with regard to state of development or points of control, there are five well-defined phases in the acquisition process for a major U.S. defense system. Such precision is not available in judging acceptability. This suggests that desirability and feasibility should be somewhat easier (albeit still very difficult) to analyze, but does not suggest that that acceptability can be allowed to trail after desirability and feasibility. From the analyst's point of view, these three criteria are circularly connected in the sense that they may be taken under consideration in any order and in the sense that an agreement or understanding, to endure, must continue to meet all three criteria from the viewpoint of both parties: it must be desirable *and* feasible *and* acceptable.[5]

* * *

While it would be an overstatement to say that we have developed techniques for definitively analyzing prospective constraints, our research has suggested three analytic approaches for testing hypothesized constraints. Although these three approaches are discussed separately, it is likely that they will be most useful if they are considered simultaneously in the process of analysis.

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[5]Again we note that we use "agreement" to include implicit as well as explicit bargains. (See Section I, footnote 10.)

THE FIRST APPROACH: JUDGING SPECIFIC SYSTEMS AGAINST THE THREE CRITERIA

In order to lend structure to the analysis of hypothesized constraints, the first step is to break the three criteria of desirability, feasibility, and acceptability into subcriteria as indicated below.[6]

Desirability:

- Interests of potential participants.
- Program life-cycle cost.
- Cost-effectiveness trend.
- Contribution to security.
- Contribution to stability.
- Uniqueness against threat.
- Degree to which weapon does needless damage.
- Impact on nuclear threshold.

Feasibility:

- Detectability.
- Phase of acquisition or stage in weapon life-cycle.
- Availability of points of control.
- Enforceability or availability of measures of control.
- Verifiability.
- Alternative weapons available.

Acceptability:

- To the Services.
- To the Congress.
- To the American public.
- To special interest groups.
- To the other side.
- To allies, friends, and other countries.

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[6] This represents only a partial list of subcriteria; others will undoubtedly emerge in the process of analysis. Further, these subcriteria could be scenario-oriented, as pointed out in the discussion that follows (p. 58), and might be interchangeable in some cases. For example, what could be considered as a desirability criterion in one case might be a feasibility criterion in another. To illustrate: a proposal may be feasible in one case because an alternative system is available; in another case, the proposal may be desirable because no alternative is available.

The second step is to make lists of existing and near-existing conventional weapons systems and then rate each of these systems according to the criteria. This can be done for both U.S. and Soviet weapons. To organize these lists, weapons might be arranged in broad categories corresponding to Land Forces, Naval Forces, and Tactical Air Forces, as is done in the *Annual Defense Department Report, FY 1977.*[7] This document and the *DoD Program of Research, Development, Test and Evaluation*[8] are good sources for U.S. weapons systems that could be considered for qualitative constraints. (Consistent lists of Soviet weapons are much harder to come by.) Tables 4 and 5, which are excerpted from tables in the latter document, provide a useful starting list for U.S. weapons to be taken under consideration; others will have to be added.

The third step is to set down the lists of weapons systems and the criteria for selection in the form of a matrix, with the weapons systems on one axis and the subcriteria on the other. For each of the subcriteria, each weapon system might be rated from, say, A through C regarding its candidacy for qualitative constraints, where A corresponds to a good candidate and C corresponds to a poor candidate. For example, if the program life-cycle cost were high, a system would receive an A; if its detectability were low, it would receive a C.

Figure 4 shows how such a matrix would look for several weapons in the land forces category, with a European scenario in mind. (The reader should not set much store by the actual ratings--we display them only to show the method.) Having filled in the matrix, the analyst needs to ask himself whether being methodical has prompted him to think of new nontrivial points.

Admittedly, this approach might seem naive or simplistic. Indeed, it does neglect many complicating factors and has several other disadvantages as well. For example, in experimenting with such matrices, it was quickly discovered that it is difficult to be consistent in the

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[7] Donald H. Rumsfeld, *Annual Defense Department Report, FY 1977*, January 1976.

[8] Malcolm H. Currie, *DoD Program of Research, Development, Test and Evaluation*, Statement to the Congress of the United States, 94th Cong., 2d Sess., February 3, 1976.

Table 4

SYSTEMS, DEVELOPMENT, TEST AND EVALUATION HIGHLIGHTS OF CY 1975[a]

SAM-D Air Defense System	Successfully completed its proof of principle track-via-missile guidance tests
XM-1 Tank	Both prototypes were delivered on schedule for competitive Army testing
AAH and UTTAS Helicopters	Both are flying with T-700 engine and meeting planned performance goals
AEGIS Fleet Air Defense	Several consecutive successful firings with the STANDARD Missile from USS *Norton Sound*
PHALANX Weapon System	Lethality against a threat missile was confirmed in a test against a sled-driven target
CONDOR Missile	Completed an extensive evaluation program, demonstrating a small CEP in firing tests
A10 Attack Aircraft	GAU-8 Cannon showed impressive lethality against armored vehicle targets
HARPOON Missile	Showed excellent performance with a high percentage of direct hits on ship targets
CLGP Artillery	Performed well against fixed and moving targets, including one hit with designation by an RPV
Imaging IR MAVERICK	Prototype successfully fired against stationary and moving tank-type targets and demonstrated high accuracy in conditions of reduced visibility
Nonimaging IR MAVERICK	Prototype successfully fired against a tank target
E-2C Aircraft	Overla[illegible] target detection/tracking capability (ARPS) demonstrated
COMPASS COPE RPV	Prototypes demonstrated their endurance and landing capabilities
SM-2 STANDARD Missile	Successfully demonstrated mid-course and terminal guidance improvements
AIM-9L Missile	Demonstrated all-aspect homing capability against nonafterburning, maneuvering targets
LAMPS MK III Airborne ASW	Successfully converted active sonar contacts to attack criteria, from an H-2 test bed
STINGER Missile	Successful test firings against maneuvering, high-performance targets using countermeasures
CAPTOR Mine	Demonstrated an effective ASW capability in an at-sea operational evaluation
MICV Combat Vehicle	Engineering development vehicles have been delivered and have demonstrated their ability to meet most performance goals
XM-198 Howitzer	Demonstrated capability to fire a rocket-assisted projectile to ranges of 30 kilometers
AN/TPQ-36 Countermortar Radar	Equaled or exceeded performance requirements for range and accuracy
AN/TPQ-37 Counterbattery Radar ...	Demonstrated ability to locate multiple simultaneous hostile artillery firings and rapid computation of counterbattery data
MK 500 Evader	Feasibility of terminal evasion shows in a highly successful flight test
Surface Effect Ship	Two prototypes demonstrated sustained high operating speeds; one set world record at 82.3 kn
ALSS Location/Strike System	Demonstrated in Europe, providing confidence in technology required for PLSS
AN/TSQ-73 Air Defense System	Capability for command and control of multiple SAM batteries demonstrated

[a]Excerpted from Malcolm H. Currie, *DoD Program of Research, Development, Test and Evaluation*, Statement to the Congress of the United States, 94th Cong., 2d Sess., February 3, 1976.

Table 5

ACTIONS ASSOCIATED WITH THE PROPOSED FY 1977 RDT&E PROGRAM[a]

• *Transition Into Production* a Number of Systems Which Are the Output of Defense RDT&E	• Provide Strong RDT&E Support for Programs in *Early Stages of Production* and for *Improvements* in Existing Systems	• *Continue in Full-Scale Engineering Development* a Number of Important Programs
UTTAS Transport Helicopter	M60 Tank	XM-1 Tank
STINGER Air Defense Missile	AIM-7F Missile	CSGN Strike Cruiser
DDG-47 AEGIS Ship	AIM-9L Missile	F16 Aircraft
HARPOON Missile	XM-198 Howitzer	F18 Aircraft
Artillery Delivered Mine	SM-2 STANDARD Missile	AEGIS Fleet Air Defense
GBU-15 Guided Bomb	MK-46 Torpedo	Tank Thermal Night Sight
Laser MAVERICK Missile	A-10 Attack Aircraft	Improved LAW Missile
CONDOR Missile	F-15 Fighter Aircraft	CLGP Artillery Projectile
MICV Infantry Combat Vehicle	COBRA Helicopter with TOW Missile	Navy Guided Projectiles (5" & 8"-unboosted)
AN/TSQ-73 Air Defense Control System	Improved Hawk Air Defense System	SAM-D Long-Range Air Defense System
PHALANX Weapon System	CHAPPARAL Missile	ROLAND Short-Range Air Defense System
		Advanced Airborne Command Post
		LAMPS III Airborne ASW
		HELLFIRE Missile
		HARM Missile
		AAH Attack Helicopter
		BUSHMASTER Automatic Cannon
		PAVE Series Bombing System
• Allow *Phasing Into Full-Scale Engineering Development* a Limited Number of Important Programs Which Have Accomplished a Significant Progress Demonstration During the Past Year	• *Defer Major Funding Commitments* and Stretch Out a Number of Important Programs	• Maintain *Options in Advanced Development*
SLCM Cruise Missile	COMPASS COPE RPV	MK 500 Evader Warhead
ALCM Cruise Missile	Advanced Hydrofoils	V/STOL Aircraft
Imaging IR MAVERICK Missile	CVNX Nuclear Aircraft Carrier	Mini-RPV (Army)
Precision Location/Strike System	Advanced Air Defense Gun	Amphibious Assault Landing Craft
		General Support Rocket System
		ASMD Missile
		Surface Effect Ship
		M-X Missile
		Navy Guided Projectile (8"-boosted)

[a]Excerpted from Malcolm H. Currie, *DoD Program of Research, Development, Test and Evaluation*, Statement to the Congress of the United States, 94th Cong., 2d Sess., February 3, 1976.

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	Desirability									Feasibility							Acceptability					
Land Forces	Interests of participants	Program life-cycle cost	Cost-effectiveness trend	Contribution to security	Contribution to stability	Uniqueness against threat	Degree of needless damage	Impact on nuclear threshold		Detectability	Phase of acquisition	Avail. of points of control	Enforceability	Verifiability	Alternatives available		To the Services	To the Congress	To the American public	To special-interest groups	To the other side	To allies and others
M-60 Tank																						
XM-1 Tank	?	A	A	C	B	B	B	B		A	A	A	?	A	B		C	B	B	C	A	B
MICV Combat Vehicle																						
TOW Missile	C	C	C	C	C	A	C	B		C	C	C	?	C	B		C	C	C	B	A	C
Dragon Missile																						
Improved LAW Missile																						
CLGP Artillery Projectile																						

Fig. 4—Matrix as partially filled in by one analyst

rating process. Consistency, if achievable at all, requires that one be both thoughtful and careful and that one have sufficient information on the weapons systems (costs, sizes, state of development, etc.). Much of the required information is difficult to obtain, even for U.S. weapons, and almost impossible for many Soviet systems.

Nonetheless, there are advantages to this matrix approach. For example, in spite of the difficulties involved in rating each weapon system against the subcriteria, we believe that it is more useful to consider each of the elements in a matrix than to try to think about the possibilities for qualitative constraints without that aid. Thus these subcriteria seem to be most useful as a *checklist* (to which more items may be added). Such a checklist should help to order one's thinking about a given hypothesis on constraints.[9]

A further advantage of the checklist approach is that it can be applied independently to a particular set of weapons systems on one side (United States or Soviet Union) and then to other sets on the other side. (Nonetheless, the effects that constraints on one side would have on needs of the other side must be heeded.) If a good candidate system on either side has been selected through the use of the checklist, it is necessary to consider likely scenarios before proceeding to consider types of agreements that might be reached with the other side. This implies an inductive rather than a deductive approach; i.e., a specific weapon system or an entire category of weapons on one side would be identified for the nucleus of an agreement before the general principles of agreement were decided on. Since many potential agreements between the United States and the Soviet Union are likely to be asymmetrical in nature, this is good.

Experienced people making the ratings would implicitly have a range of likely scenarios in mind. Once detailed attention is paid to a candidate system, more could be done to consider it in contexts that would include both noncombat or deterrent values and combat values. Additionally, the consequences of asymmetrical constraints would need to be

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[9] Incidentally, ACDA may find some use for matrices of this sort in complying with the Congressional mandate requiring impact statements on new weapons. A similar format might be used as a presentation device, giving a degree of uniformity.

further explored. (For example, could the United States limit the introduction of modern fighter bombers to Europe if the Soviets did not limit modern armor, etc.?)

The Need for Subjective Judgments

In attempting to apply the criteria for selection of weapons systems for qualitative constraints, it becomes clear that subjective judgments must enter into the work in at least three ways (even in the cases of desirability and feasibility criteria, which can rely in part on hard quantitative data).

First, the degree of detail used in characterizing each weapon system would get out of hand unless some judgment were exercised regarding the likely relevance of that detail. For example, the air-to-ground missile Maverick could use any of three existing guidance schemes, while at least three other new schemes are under consideration, plus various possible miniaturized successors. But it is probably necessary to consider only the gross characteristics of this family of weapons, namely, that they are terminally guided and on their own after being launched from airplanes at certain stand-off ranges.

Second, many potential candidate systems could be subjected to extensive performance and cost analyses and consume hours of computer time. (As already indicated, the treatment of cost savings becomes more and more complex as it is considered more carefully, and it could well take a full report to treat the rules for estimating these savings.)

Third, as mentioned, most political judgments are necessarily subjective.

Thus it is necessary to rely on a combination of objective and subjective judgments, sometimes in the cases of the desirability and feasibility criteria, and always in the case of acceptability criteria. This implies that such judgments should be carefully examined and re-examined by informed analysts and arms control authorities before becoming the basis of any action.

The Time-Frame Problem

The method we have discussed is most readily applied to existing and near-future systems whose characteristics and military uses are

fairly well understood. However, there is a natural conflict between concentrating on such systems and on much less well defined future systems. The following factors are relevant in dealing with this time-frame problem:

1. Experience shows that the establishment of arms control agreements requires long lead-time preparations--the SALT and MBFR negotiations are cases in point. Therefore, anticipating and accounting for what will become contemporary weapons developments in the time frame of completed negotiations is essential.

2. The importance of focusing on anticipated as opposed to current qualitative arms advances is underlined by the historic precedents for the argument that it is much easier to limit or prohibit development of weapons or weapons improvements that are not already in the arsenal in number. (It is also easy to limit weapons that have little or no useful life left.)

3. If future trends are considered, it appears possible that some very expensive new weapons systems could become less useful or less attractive because of their increasing vulnerability to PGMs and RPVs, or because of the possibility that they could be replaced in part by PGMs and RPVs. If this is true, these systems may become more amenable to qualitative constraints.

4. On the other hand, we do not know how countermeasures, counter-countermeasures, and new tactics will affect the value of the relatively untried new types of systems, especially PGMs and RPVs, nor how they will evolve.

Thus, the dilemma we face is that (a) we would like to include appropriate weapons of the future in our consideration of possible qualitative constraints, but (b) there is considerable uncertainty as to which weapons will be most important in the future. The two approaches to analysis discussed below anticipate this dilemma.[10]

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[10] We call these "second" and "third" approaches only to facilitate discussion. As pointed out above, they really should be considered simultaneously with the checklist approach. Reiterating what Amrom Katz said in his article cited above, considerations can be simultaneous, but discussion has to be sequential.

THE SECOND APPROACH: FORECASTING

An analyst with an appropriate background might paint a picture of land, sea, air, and space warfare 15 to 20 years from now in an attempt to gain some insights about weapons systems that will be needed most by that time and those that will not be needed, or that will be needed only in small numbers for special purposes. Systems in the two latter categories might be good candidates for qualitative constraints.

To go about this, one might begin by studying available official documents. (At any given time there are usually fairly recent forecasts available, prepared by the services, in which they have projected their expectations of needs and what their forces will be like 15 to 20 years in the future.) Unofficial forecasts are frequently published in the open literature.[11]

It will be much harder to find reliable treatments on the Soviet side. Nevertheless, various reports on Soviet technological progress, prepared by the Director of Net Technology Assessment, Office of the Director of Defense Research and Engineering, should be useful to some extent in forecasting.

In addition, of course, analysts could well benefit from direct discussions with military force planners, and those involved in forecasting. With the background provided by such discussions and by forecasts available both in official and unofficial form, it will then be up to the arms control analyst to form his own hypotheses about constraints and to test them. Having constructed a picture of what the future holds militarily, the analyst could consider many of the same subcriteria mentioned earlier.

Naturally there are both difficulties and dangers. Since it is impossible to predict accurately the course of warfare 15 to 20 years from now, unexpected problems of new systems may make a nation wish it had retained the traditional weapons.[12] Nonetheless, careful attention

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[11] Two rather recent examples of such forecasts are W. B. Graham, *A Look to the Future*, The Rand Corporation, P-5251, June 1974, and P. A. Wilson, "The Marine Corps in 1985," *U.S. Naval Institute Proceedings*, January 1976, pp. 32-38.

[12] The quantitative-qualitative form of agreement discussed in Section VI would be a hedge.

to the delineation of future trends seems a prudent part of any endeavor to identify potential constraints on conventional arms, because an important task of U.S. arms control analysts is to identify limitations that might foreclose systems whose future value cannot be known at the time such a decision is made.

THIRD APPROACH: MODELS AND TEST QUESTIONS

A third method, which we treat only briefly, involves (a) constructing models of future U.S.-Soviet confrontations first with, and then without, postulated qualitative constraints, and (b) posing a series of test questions to determine the impact of the postulated constraints. The models might be relatively detailed or primarily expositional. The test questions might ask, for example: Do other systems "cover" for constrained systems? Do unconstrained nonweapon systems (e.g., command-control or rapid transport means) compensate for constrained weapons, and do these make for stability? Are the constrained weapons becoming more and more subject to being countered? Does the understanding or agreement capitalize on asymmetries in U.S. and Soviet value systems?

The models and test questions should acknowledge a variety of forms of agreement, each different in the time lags to implementation and ease of abrogation. The systems chosen for constraints in the "with constraints" part of the testing must be selected with care to ensure inclusion of those most relevant in terms of the incentives noted on p. 10. Although this approach increases the likelihood that the analyst will be trapped into immense complexities and irrelevant detail, it has the advantage of enabling him to test the heuristic hypotheses in terms of total force posture. It will also facilitate his thinking about political contexts and scenarios over time. All of these factors are important in assessing the consequences faced by each side in foregoing certain weapons. Implicitly or explicitly, an analyst needs to have such models in mind as he rates each weapons system A, B, or C for such factors as "contribution to security" and "contribution to stability," as suggested in the first approach.

* * *

We conclude this section, which we consider only suggestive of analytical techniques, by cautioning the reader that any analysis that breaks up big complex questions into smaller ones runs the risk of neglecting important interactions. For example, Soviet nuclear postures greatly affect U.S. nonnuclear requirements. Soviet needs, on the other hand, are affected both by the Chinese threat and by the Soviets' concern over U.S. military capabilities. And regional instabilities and arms transfers may pose more immediate problems than bilateral concerns, particularly with respect to the types of weapons we deal with in this study.

In view of this complexity, the road ahead will be a difficult one both for analysis and for the negotiation of conventional arms constraints. The heuristic approach--setting forth hypotheses and then testing them--is a good one. We believe that such testing, even in terms of values that cannot be stated quantitatively, will best be done with the aid of methodical structures of the sort we have described here.

V. WORKING WITH ASYMMETRIES

The preceding section has made it clear that many elements will have to enter into a decision to constrain conventional arms and that the evaluation of proposals will be a very complex process. In an attempt to simplify matters, some people may propose exactly symmetrical arms limitations by the two superpowers. Such suggestions have been made in connection with SALT. But to get the greatest value--as rated by the value systems of each side--any agreement or understanding on qualitative constraints will probably have to be asymmetrical.

The military balance between the United States and the Soviet Union has always been characterized by asymmetries--aspects that reflect different doctrines, resources, and strategic situations. America has generally been well ahead of the Soviets in advanced technology, especially relative to offensive forces at sea or in the air, whereas the Soviets have maintained larger land forces and more extensive antiaircraft and coastal defenses.

Many of these asymmetries have been a natural product of geography and history, and each side has opportunities and problems conferred by its geographic position. For example, the Soviet Navy must operate from home ports separated from the open oceans by narrow seas and straits; they have until recently neglected the long-endurance bluewater ships that the U.S. Navy emphasizes (one exception, Petropavlovsk, is a secondary base on the open ocean, but it is ice-bound much of the year). The United States, on the other hand, has been forced by its location to develop ways of transporting military forces and their supplies over great distances, and has long had highly developed air and sea transport systems. (This is an area where the Soviets have shown great improvement in recent years, as evidenced by their performance during the Arab-Israeli War of October 1973.)

In addition, each side's history has affected its present-day practices. The Soviet military, for example, apparently puts great emphasis on the value of a rapid thrust in a conflict against NATO, an emphasis quite likely inspired by Marshal Malinovsky's success in the Manchurian

campaign of 1945. It is only recently that the influence of this campaign on current Soviet military strategy has been carefully studied in the United States. This research indicates that the "Manchurian model" was the focus of historical research by the Soviet General Staff in the 1960s and has influenced Soviet strategy ever since. Reports on these studies, notably a 1966 book by Colonel L. N. Vnotchenko,[1] have put forward the Manchurian campaign as the main offensive model for strategically decisive modern operations. "The outstanding features of this campaign, aside from the relatively light casualties incurred by Soviet forces, were the size, suddenness, speed, and depth of its initial operations. . . . Such stunning success has thus made it an exceptionally attractive model for modern military emulation."[2] The Manchurian model, with its stress on combined-arms operations, also served as a vehicle for the professional military to oppose the resource-saving, predominately nuclear, strategies imposed by Soviet political leaders in the early 1960s.

Because the Soviet strategy does reflect the Manchurian model, it differs from American strategy in many aspects. It would be quite a departure from American military policy, for example, if U.S. maneuver battalions were backed only by Soviet-style divisional support, with minimal repair facilities for expensive vehicles. Similarly, U.S. observers have wondered why Admiral of the Fleet of the Soviet Union S. G. Gorshkov, in his articles on naval strategy,[3] gave so little heed to the interdiction of NATO's sea lines of communication, a function whose countering requires great expenditures on the part of NATO. Conceivably, a "Manchurian" point-of-view could account for the Soviets' giving less weight to sustaining a longish war.

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[1] L. N. Vnotchenko, *Pobeda na Dal'nem Vostoke* [Victory in the Far East], Voenizdat, Moscow, 1966.

[2] Quoted in John Despres, Lilita Dzirkals, and Barton Whaley, *Timely Lessons of History: The Manchurian Model for Soviet Strategy*, The Rand Corporation, R-1825-NA, July 1976, p. 2.

[3] These articles appeared in *Morskoi sbornik* and were translated, in eleven installments, in the *United States Naval Institute Proceedings*, January to November 1974. (The original articles appeared over a period of thirteen months, beginning in January 1972 and ending in February 1973.) A summary by Robert G. Weinland et al. appears in *Survival*, Vol. 17, No. 2, March/April 1975, pp. 54-63.

It is important to recognize these asymmetries and the openings they may provide for qualitative constraints in conventional armaments. For example, since the Soviet Union does not currently build large aircraft carriers, it would not be productive to seek a symmetrical agreement in this area. On the other hand, past Soviet postures have shown a grave concern over the threat from *our* aircraft carriers, so they may be willing to reduce the number of a given quality of attack submarines in exchange for our reducing the number of aircraft carriers that exceed certain performance characteristics. This is a qualitative-quantitative constraint, as discussed in Section VI.

ASYMMETRIES IN DEFENSE ECONOMICS

Economic incentives for U.S. curtailment of certain conventional arms programs include straightforward savings in procurement costs as well as in downstream operations and support costs. Such curtailments are likely to be more acceptable if they are consistent with the long-term plans of top defense officials in terms of moving toward a planned future posture.[4]

Would these economic incentives also apply in the Soviet Union? There, resources released by limiting development and production of conventional arms may either be used elsewhere within the military sector or else transferred to the civilian sector. If Soviet leaders were to perceive a need for either kind of reallocation, there would be an economic incentive for conventional arms control parallel to the incentive for the United States. Many Western students of the Soviet economy have argued that the defense sector in the USSR operates in a unique bureaucratic and planning environment such that resources redirected from the military to the civilian sector would, in the short

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[4]The recent U.S. MBFR proposal to give up 1000 nuclear warheads in Europe if the Soviets would reduce the number of tanks by 1700 is a useful example to consider in this regard. The Defense Department, spurred by the Senate's 1974 Nunn Amendment, had already begun to "rethink" the U.S. nuclear weapons posture in Europe in terms of modernizing it by replacing some nuclear weapons with nonnuclear ones. Thus this proposal is, on the surface, probably compatible with long-term plans. However, it also serves to illustrate the necessity for careful staffing; if dual-purpose aircraft were given up along with the nuclear weapons they could carry, it would impede U.S. efforts to transfer certain tasks from nuclear to nonnuclear systems.

run, be expected to yield a less than proportional increment of output. The size of this penalty on reallocation would vary with the nature of both the defense activity curtailed and the civilian branch to which the resources were directed.[5] But if this argument is also supported by Soviet leaders, they may well be less than impressed with the potential economic gains from constraining conventional arms. However, Soviet leaders are also acutely conscious of the scarcity of resources for the multiple objectives pursued by the regime--industrial growth and improvements, as well as defense and international political status. A sizable cut in military expenditures would be attractive on economic grounds even if there were some penalty on reallocation out of the military sector. For small changes, we suspect that economic motivations will play a relatively insignificant part in Soviet thinking with respect to qualitative constraints on conventional armaments.

ASYMMETRIES IN NATIONAL OBJECTIVES

It is also important to recognize asymmetries in national security objectives between the two superpowers, especially as applied in Europe.

The U.S.-NATO posture in Europe is basically defensive; its aim is to protect Western Europe against aggression from the Warsaw Pact countries at times and places not of its own choosing. However, NATO's peacetime standing armed forces are inferior in numbers and in readiness to those of the Warsaw Pact countries, and the rapidly developing Soviet Navy could well cause the Atlantic Ocean to be an especially hostile barrier to the movement of U.S. forces and supplies in spite of the fact that Gorshkov paid small heed to the interdiction of NATO's sea lines of communication.[6]

The posture of the Warsaw Pact forces facing NATO, on the other hand, is primarily offensive. This offensive capability is embodied in a quantitatively superior force along their western frontiers. The

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[5] See the appendix by Andrew Marshall in U.S. Congress, *Allocation of Resources in the Soviet Union and China--1975*, Hearings Before the Subcommittee on Priorities and Economy in Government of the Joint Economic Committee, Part I, 94th Cong., 1st Sess., released October 26, 1975.

[6] Gorshkov, op. cit.

force is composed of a large number of highly mobile armored and mechanized divisions. Coupled with this offensive force is the Pact air defense system, consisting of numerous radars, a variety of mutually supportive precision-guided surface-to-air missiles, and many interceptor aircraft. This air defense capability poses a formidable threat to the qualitatively superior NATO air forces.

Another asymmetry is the necessary Soviet concern for guarding its long border with China. While there are a number of indications of the primacy of European matters in Soviet military force postures, nonetheless, the threat of military action--or even embarrassment--by China must be dealt with, and will continue to affect any Soviet evaluation of constraints on arms.

To reiterate: technologically, the West is somewhat superior to the East, which may enable it to develop and benefit from more effective new weapon systems.[7]

Unfortunately, the Pact's quantitative superiority may grow as the result of the continuing high rate at which tanks, airplanes, and similar weapons are being produced by the Soviet Union and the Warsaw Pact nations, and as a result of their ability to augment production and increase their standing armed forces over the medium term more easily than the West. Such a widening gap is quite likely to have a destabilizing effect in the NATO-Warsaw Pact balance.

CAN QUALITY SUBSTITUTE FOR QUANTITY?

A key question for U.S. planners is the extent to which quality can substitute for quantity. As just noted, in some fields the West is superior to the Soviets, and this may enable us to continue to develop and produce more effective new weapons systems. There are possibilities that these new weapons will be able to compensate--to an undefined extent--for our quantitative inferiority. Thus, the Soviets may find

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[7] For a discussion of the quantitative and qualitative balance, see John M. Collins and John Steven Chwat, *United States/Soviet Military Balance: A Frame of Reference for the Congress*, Library of Congress, Congressional Research Service, January 1976. Excerpts from this study, which was requested by Senator John C. Culver, are given in Appendix B.

the general notion of qualitative constraints on high-technology systems attractive--a point that must be noted with caution by U.S. officials.

From this point and the preceding discussion, it appears as if one useful classification of conventional arms control agreements would be (1) those that constrain numbers by weapon class, (2) those that primarily constrain the number of systems by size class (as in the Washington Naval Agreement), and (3) those that primarily constrain high-technology weapons. The complexities involved in getting an agreement along any one line will be summed up at the end of this section.

The factor by which quality can compensate for quantity must be evaluated and defined in order to make value judgments on the amount of qualitative constraint we can judiciously agree to. One method of evaluating the tradeoff between quality and quantity is to use a model based on the "square law" of F. W. Lanchester, which is an elegant, if restricted, formulation.[8] This law states that winning is proportional to efficiency directly and to the square of quantity. Army Under Secretary Augustine put it this way:

> Just how important is numerical superiority on this battlefield? Certainly, qualitative superiority can go a long way toward offsetting numerical disadvantages. The atomic bomb is, perhaps, the extreme example of this. But setting aside the case of weapons of mass destruction, it would appear that qualitative superiority has some very real limitations.
>
> In 1916 the British engineer, F. W. Lanchester, showed that to match a foe with twice as many weapons as one's own, one must possess weapons not of twice the quality of the enemy's but rather *four* times the quality. That is, quantitative superiority is favored by the presence of a "square"

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[8] One version is this: $dX/dt = -bY$; $dY/dt = -aX$, where X and Y are the sizes of x's and y's force, and a and b are "efficiency constants" that tell how fast a unit of X can kill a unit of Y, and vice versa. Thus the rate at which X is attrited is proportional to Y's size and its efficiency constant b. This reduces to $aX(dX/dt) - bY(dY/dt) = 0$. Integrating, $aX^2 - bY^2 = C_0$, and "X" wins if $(a/b) \cdot (X/Y)^2 > 1$. (From F. W. Lanchester, *Aircraft in Warfare: The Dawn of the Fourth Arm*, Constable and Company, London, 1916.)

law, whereas the advantages of qualitative superiority assert themselves only linearly. Because of the limited applicability of the case analyzed by Lanchester, it has often been argued that the proper exponent is something less than two but certainly greater than one.

Nonetheless, it is very difficult indeed to offset major numerical disadvantages with quality alone--and nearly impossible to do so when the enemy combines quantitative superiority with reasonably high *individual* weapon effectiveness. This point has certainly not been missed by the Soviet Union which has not only amassed very large forces but has embraced Lanchester's principle by including it in such publications as *Anti-tank Warfare*, by Biryukov and Melnikov.

The applicability of Lanchester's analysis is, of course, affected by the tactical situations. For example, it is generally assumed that forces on the defense are favored by a factor of 3 to 5 in terms of required strength to produce a stalemate. Lanchester's analysis applies principally to a case wherein shifting tactical situations tend to counter-balance such effects. As the Secretary of Defense has noted, when Daniel Boone, who shot 50 bears a year, was replaced by 50 hunters, each of whom shot only 2 bears a year, there is no record of the bears celebrating the decline of human marksmanship.[9]

However, the Lanchester approach is only one way to look at the tradeoff between quality and quantity. Another measure, which can be either simple or quite complex in its application, is the use of firepower scores. These scores are used not only in analysis, but also by the umpires who judge outcomes in military field exercises.[10] Beyond this, there are computer models of various degrees of complexity, up to those costing many thousands of dollars to run.

All of these methods are quite thoughtfully discussed and held up for examination by J. A. Stockfisch in a recent report.[11] He notes that

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[9]Norman R. Augustine, "One Plane, One Tank, One Ship: Trend for the Future?" *Defense Management Journal*, Vol. 11, No. 2, April 1975, pp. 36-37.

[10]See *Maneuver Control*, FM-105-5, Department of the Army, December 1973.

[11]J. A. Stockfisch, *Models, Data, and War: A Critique of the Study of Conventional Forces*, The Rand Corporation, R-1526-PR, March 1975.

> The use of combat models to simulate combat and campaigns requires data, which are inputs for the models. The quality or worth of the findings of any model is a function of both the model's structure and the quality, or relevance, of its data inputs. This Report critically surveys both of these components.
>
> The major positive recommendation of the Report, aimed at armed forces decisionmakers--specifically, those involved with weapon-system development, evaluation, and testing, as well as force planning--is that relatively more emphasis must be placed on empirical work, and particularly on operational testing. [p. iii]

The point of all of this is that careful military analysis based on good data has much to say on how far quality goes in replacing quantity.

* * *

Because it is so difficult politically for the West to increase military budgets and manpower allocations to military service, especially over the medium term, it is prudent for the Allies not to foreclose efforts on qualitative improvements, especially improvements that benefit the defense or that would aid our forces in dealing with Soviet numerical superiority.[12] The United States would be most uncautious to enter into such an agreement without thoughtful analysis, including a careful look at the range of future prospects, as discussed in Section IV. The importance of such analysis can be seen by considering both Soviet and U.S. motivations to agree to constraints of the types classified on p. 69. For example, those agreements that would constrain numbers by weapon class would encounter the Soviet tendency to produce great quantities of weapons, since the Soviets give less weight to the costs of producing and manning them than we do. To get an agreement

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[12] The authors are by no means saying that the salvation of U.S. and NATO posture lies in high technology alone, or that the high-technology systems are soon going to work so well that they will revolutionize our defenses. Some balance between quantity and performance is clearly needed, and new technology can also be used to reduce costs and facilitate larger numbers. What we do say is that the United States must beware of foreclosing technical opportunities.

that would limit quantities by size class (for the larger sizes) would be difficult unless the United States and NATO were well along the road toward being able to deal with those large sizes of weapons with our PGM counterweapons.

Thus some concessions, in an asymmetrical agreement, to limit our high-technology systems may be a required bargaining element. Our concern about the unknown consequences of such constraints would be somewhat lessened if agreements were to take the form of qualitative-quantitative constraints discussed in the first part of the next section.

PART FOUR: SOME EMERGING ARMS CONTROL OPPORTUNITIES

VI. FORM OF CONSTRAINTS, CANDIDATE SYSTEMS

This section treats arms control opportunities in two ways: (1) by discussing what we regard as the most promising form of qualitative agreement for the United States--one in which weapons with specified characteristics would be limited in quantity rather than subject to a complete prohibition; and (2) by mentioning some systems that may be candidates for some form of limitation.

QUALITATIVE-QUANTITATIVE CONSTRAINTS

As defined in Section I, the most restrictive form of qualitative constraint would prohibit the development, testing, production, and operational deployment of weapons systems that fit into an agreed-upon definition. However, a combination of qualitative and quantitative constraints, where the numbers of systems having certain qualities are not reduced to zero but rather to an agreed-upon quantity, is another possibility. This type of constraint would probably be the most acceptable to the United States. Such constraints could be applied at either the production or deployment level. From the U.S. point of view, such agreements would be less dependent on the exceedingly difficult verification of what is happening in Soviet laboratories or testing grounds. At the same time, the United States could carry qualitatively advanced weapons to the point of pilot production and depend on our relatively strong capabilities for mass production of the most recently developed weapons to save the day if it were found that the Soviets had abrogated the agreement--and if there were time. Moreover, such an agreement would at least achieve some of the economic benefits of limitation, especially the avoidance of large-scale procurement, maintenance, and manpower costs, and at the same time it would permit our industrial technology base to remain at the forefront of the relevant technologies. (However, because we typically spend 15 to 25 percent of total procurement funds prior to large-scale production, defense contractors would have to raise unit prices to stay in business.) In the United States, this kind of agreement might also be more acceptable from a political point of view, since plants would not be shut down.

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Some examples may illustrate the two types of agreement. A purely qualitative agreement might prohibit the development and production of cruise missiles that could be launched from submerged platforms. Qualitative-quantitative agreements might take several forms, exemplified by the following hypothetical cases: (1) the two parties might agree to produce no more than 200 tanks per year at a weight exceeding 30 tons; or (2) they might limit air-launched cruise missiles to those that could be carried on 100 aircraft; or (3) they might limit to 200 the number of fighter-bombers over 25,000 lb in the NATO Central Front region.

Note that this form of agreement is in some respects the antithesis of Herbert York's 1972 Pugwash suggestion[1] for gradual demobilization of manpower and facilities devoted to secret military R&D. There York distinguished between open installations and secret installations, and considered the demobilization of the secret ones with a transfer of personnel from secret to nonsecret projects.

It is interesting to contrast York's idea with the view expressed by Representative Edward I. Koch (D-NY):[2]

> [We] liberals, too, are guilty of narrowness of purpose and knee jerk responses. Many in the liberal community are too busy fighting an ideological battle--one of less cost through less defense--rather than the battle we can win: Better conventional weapons at less cost.

In a context indicating that he favored military R&D, but thought much of it was in the wrong direction, Koch continued:

> So the key to survival is obvious: Quantity and low cost. We must build a lot of cheap planes, ships, and motorized vehicles instead of a few costly ones.
>
> This change in tactical warfare requires two new approaches:
>
> - Stop building weapons which cost so much that we cannot afford to replace them if they are destroyed, as they will be in large numbers.

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[1] "Some Possible Measures for Slowing the Qualitative Arms Race," Paper XXII-P-III, 22nd Pugwash Conference, Oxford, September 1972.

[2] *Chicago Tribune*, December 15, 1975, p. 19.

- Orient our research and development to take men out of vulnerable machines. We cannot make the machines materially safer, but we can make them remotely piloted.

For the analyst interested in the acceptability of qualitative constraints, a careful reading of Koch's entire article is indicated; it may imply a common ground between political elements who have been identified as opposing an arms buildup and other elements whose main interests have been the improvement of U.S. defenses.

The debate between those who advocate the development of new military technology and those who call for severe restrictions on such development is highlighted in a recent series of articles in *Foreign Policy*. In a summary treatment, Albert Wohlstetter compares the latter group with the Luddites, the group in nineteenth-century England who sought to hold back the industrial revolution by destroying machines.[3] We believe such restrictions are often wrong for the U.S.; they can in some cases run against important aims of arms control. This is because new technology can sometimes make for less resources going into arms. It may also permit a new precision in the physical aiming of weapons, which in turn permits a new precision in the purposes for which military forces are applied. New technologies can make forces less vulnerable, more responsive to political control, and less costly.

PRELIMINARY VIEWS ON SOME CANDIDATE SYSTEMS

Although it is premature to forecast which issues ACDA may have to face as qualitative limitations are discussed over the next few years, it seemed useful to note some of the factors that may be considered with respect to systems that have been mentioned in the press or at the MBFR talks as candidates for arms limitations. This is in accord with our belief that arms limitations ultimately must be discussed in concrete terms, rather than in terms of abstract principles. However, we must strongly warn that the points made here are tentative and incomplete.

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[3]Albert Wohlstetter, "Optimal Ways To Confuse Ourselves," *Foreign Policy*, No. 20, Fall 1975, pp. 170-198.

The particular systems discussed below were *not* derived from any of the analytic methods mentioned in Section IV. Rather they might serve as a starting point for the heuristic approach discussed there, which requires that hypotheses be set forth about certain policies, and then tested. So, for each example, the reader should first ask himself, "Is this hypothetical constraint worthy of more careful investigation?" The methods mentioned in Section IV are only a beginning and imply the need for a great deal of careful staff work, which would go far beyond the practical limits of the present research. Nonetheless, we believe that many of the factors mentioned in the discussion that follows could be useful in ACDA's later analyses of these issues. Note that most of these systems would have nuclear applications as well as nonnuclear ones, and that labeling them as "strategic" or "tactical" may be more confusing than helpful.

Cruise missiles have already become an issue as a concomitant of SALT. The Soviets want to count them (assuming the range capability the United States plans for the "strategic" version) and the United States originally said it intended not to count them. *The New York Times*, in an editorial, recommended that the United States abandon plans to test cruise missiles, saying that under the U.S. SALT II proposals there would be no limits on sea- and land-based cruise missiles, and few on air-launched missiles. "This would permit deployment of tens of thousands of nuclear-armed cruise missiles. The Vladivostok ceiling could hardly survive such a deployment."[4] Behind this statement is the concern that cruise missile payload can easily be traded for range and that nuclear and nonnuclear warheads can be readily interchanged. These properties would make them wild cards in the SALT agreement. For example, a reconnaissance photograph could not distinguish a 200-mile nonnuclear anti-ship missile from a 1500-mile nuclear missile. In fact, it would not be difficult to test both engine and airframe for a full 1500-mile-range missile by orbiting the missile within the confines of a small area.

On the other hand, cruise missiles fit very neatly into our picture of future combat, where large numbers of hard-to-detect vehicles of

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[4] *The New York Times*, October 21, 1975, p. 36.

modest size would be preferable to fewer large, more visible vehicles. Henry S. Rowen, in Congressional testimony,[5] put it this way:

> The cruise missile incorporates basic technology that is bringing about a revolution in military capabilities and doctrine. The increasing precision possible in the delivery of weapons, even at very long ranges, is making possible the substitution of small weapons for large ones. This greatly increases the effectiveness and discriminateness with which force can be applied. Small nuclear weapons can be substituted for large ones and, most importantly, for many missions it may be possible for nonnuclear warheads to be substituted for nuclear ones. These developments will do a great deal to help set limits to the scope and level of conflict. And the prospect of being able to take more effective action, with less collateral damage, will enhance the deterrence of a significant range of action against our interest. We should not only seek to have such capabilities ourselves, we should also encourage the Soviets to move in this direction. [p. 51]

As to *detectability after launch*, the present requirements for the U.S. Navy's Sea-Launched Cruise Missile call for a radar echoing area that is less than that of a seagull. As is implied in Rowen's testimony, the substitution of cruise missiles for penetrating fighters, penetrating bombers, and carrier-based airpower (to the extent that they can handle the tasks assigned to them) promises to save money, especially due to the use of smaller platforms (e.g., missile frigates could be used in place of aircraft carriers). These are all strong arguments against including cruise missiles in any type of arms constraint agreement.

Aircraft carriers as objects for qualitative limitations--for example, in an agreement to acquire no new carriers over 40,000 tons--introduce arguments opposite to those for cruise missiles. For many jobs, CVNs[6] seem to involve greater expense than alternative means. Whether or not they would be capable of continuing combat operations in the face of a major missile attack is uncertain despite strong programs

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[5]Reprinted in *Aviation Week*, September 22, 1975, pp. 51-56.

[6]CVN is the conventional abbreviation for a nuclear-powered aircraft carrier; SSGN and SSBN are abbreviations for missile-equipped attack submarines and ballistic missile submarines, respectively. The final "N" designates nuclear propulsion.

to thwart such attacks. Most important, they cluster great military value in a single, easily tracked platform. For many years, their role in the launching of strategic nuclear strikes has been secondary to that played by other systems. Now their role in blue-ocean reconnaissance and sea control could potentially be shared with space systems, land-based airpower, and V/STOL support ships.[7]

On the other hand, in less-hostile environments, the large U.S. carriers provide a multiplicity of useful functions in presenting a formidable naval presence and in projecting power ashore. They can support amphibious landings, provide invading forces with close air support, and send out air strikes at a high rate. Advocates of the larger-size U.S. carriers point to efficiencies in putting many functions on one vessel, with several combat units sharing overhead and support functions.[8] Fifteen years ago the risks of doing this were less, since a combat-ready task force had an impressive self-defense capability. While U.S. carriers still have an impressive self-defense capability, the erosion of the U.S. naval order of battle makes it unlikely that enough ships could be assembled to provide each carrier with the sort of escort once thought essential; and even if this could be done, it is doubtful if they could adequately protect the carriers against heavy attacks by cruise missiles.

Attack submarines continue to be produced at an imposing rate by the Soviets. One knowledgeable observer, Michael MccGwire, points to the rationale for this program as extending back to 1957-1958, when concern over strategic nuclear strikes from U.S. carriers had mounted.[9]

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[7]The word "potentially" is significant here, because (a) the United States does not have very advanced ocean reconnaissance, (b) land-based air for naval functions is limited, and (c) V/STOLs and their platforms are a long way from reality. That the United States does not have these systems is largely due to our choices and official priorities, not to their infeasibility.

[8]See "A Navy Staff Study Calls Big Carriers Less Costly," *The New York Times*, November 26, 1975, p. 54.

[9]See "Soviet Naval Programmes," *Survival*, Vol. 15, No. 5, September/October 1973, pp. 218-277. This article draws on MccGwire's periodic conferences on the Soviet Navy held at Dalhousie University, Halifax, Nova Scotia.

A new requirement for nuclear submarines was laid down; they must be able to attack surface ships without external help. Some nuclear submarine construction was diverted from SSBNs to cruise-missile-carrying SSGNs (notably the Echo I and Echo II classes). At the same time, a major step-up in the construction of nuclear-powered submarines was put into effect, including construction of the Charlie-class SSGN.

We thus surmise that the Soviets, who should now be less concerned over carrier-based nuclear strikes, might limit SSG deployments in return for some U.S. concession. This feeling is reinforced by the minor attention paid to the antishipping role in the authoritative series of articles by Admiral S. G. Gorshkov mentioned in Section V[10] and by reports of high out-of-commission rates of the submarine fleet. For nonnuclear forces, the important consequence for the United States would be a diminution of the threat to shipping and ocean resupply, with the possibility of reducing somewhat the rather large amounts now going into antisubmarine warfare. With the United States and Soviet position so asymmetrical in SSGs (as in CVNs), any agreement about SSGs would probably be asymmetrical.

Tanks might also be objects for asymmetrical limitation. There has already been a proposal to decrease U.S. tactical nuclear weapons in Europe in exchange for a Soviet decrease in tanks. Tanks in motorized rifle divisions facing NATO have increased by 30 percent over the past 10 years.[11] The proliferation of more effective antitank weapons, however, would make the value of this Soviet numerical increase uncertain. In the future, defense against an armored thrust might be built around light PGM-equipped vehicles, whereas tanks would be used in a more selective fashion for offensive tactics. Because of the need to avoid being seen by opposing PGM crews, sizes--especially heights--are likely to be reduced, and current bulky tanks may then be considered obsolete.

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[10] See footnote 3 in that section.

[11] U.S. Congress, *Allocation of Resources in the Soviet Union and China--1975*, Hearings Before the Subcommittee on Priorities and Economy in Government of the Joint Economic Committee, Part I, 94th Cong., 1st Sess., October 26, 1975, p. 103.

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Fighter-bombers may be subject to many of the same kinds of influences. Ground-based air defenses have an inherent advantage in tracking an aircraft that reflects and radiates energy and contrasts vividly against the background of the sky. Thus, procurement of expensive multifunction penetrating strike aircraft (with an essential accompaniment of expensive defense suppression systems) may well shift toward standoff RPVs and PGMs, launched either from the ground or from cargo-type aircraft. (This substitution may be efficient even though separate additional aircraft may be required for some roles.) This shift may make it appropriate to consider aircraft of the F-14 and F-15 class as candidates for mutual limitation, a move for which the United States would have a strong budgetary motivation.[12]

* * *

Thus there appear to be a number of systems that are worth considering in terms of limitations--symmetrical, or not symmetrical. As pointed out at the beginning of this section, potential constraints involving these systems need to be tested and retested as described in Section IV before a firm proposal can be put forth.

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[12]For more background on these points, see James Digby, "PGMs--Changing Weapon Priorities, New Risks, New Opportunities," *Astronautics and Aeronautics*, Vol. 14, No. 3, March 1976, pp. 36-46.

VII. SUMMING UP

At this point, we would like to stand back and discuss arms control in terms of three general categories of weapons: (1) nuclear arms; (2) large, penetrating, conventional weapons systems; and (3) precision-guided or remotely controlled conventional weapons.

The first category, nuclear arms, has now been subject to a de facto control (in use, not in deployment) for the past 30 years because the effects of their use have been considered too great for any military task their possessors have had, or the sequels to their use too uncertain. This reluctance to use these weapons has both slowed nuclear proliferation (for the time being) and facilitated SALT.[1] But the formerly neat categories of weapons tasks--nuclear or nonnuclear, strategic or tactical--are being eroded by technological changes. At the same time, the focus on set-piece salvo exchanges between the superpowers, which for so many years dominated thinking about nuclear arms control, is now being broadened. (Such exchanges have never dominated the plans of the lesser nuclear powers.) Thus progress may come from exploring mutually acceptable constraints on how nuclear weapons would be used, not just constraints on arsenals.

Weapons of the second category--large, penetrating weapons systems of familiar types (for the United States, these include, for example, the XM-1 tank, the CVN, and the F-111D)--are becoming more expensive and in some cases more vulnerable to precision weapons. As a consequence, these generic types may become self-limiting. This may take 10 years or 30 years, but it seems likely if not inevitable. If so, why should ACDA bother to consider weapons in this category as possible candidates for the application of qualitative constraints? There are several reasons. First, a great deal of money might be saved by anticipating this trend (just as a great deal was saved by the Washington and London naval treaties). Second, there is concern over the destabilizing

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[1] Despite this logic against proliferation, some observers believe that the world may be perilously near a great surge of nuclear weapons acquisition by developing countries.

influences created by these symbolic weapons, especially as oil-rich countries buy them. Third, there is uncertainty as to how the trend will go with time, tempered by the fact that traditional systems can be the platforms for the most efficient modern weapons, while their vulnerabilities can be postponed through the suppression of their natural enemies. But if ACDA is to do the doable, this seems to us to be the *immediate* area where agreements or understandings should be sought.

By contrast, weapons of the third category--modern precision and remotely piloted weapons--are becoming more central to military postures and more deserving of the attention over the long term of those concerned with controlling arms or limiting their use. Their control promises to be a most difficult task, both because there can be so many producers of such arms and because the incentives to buy them or possess them are so great.[2]

In fact, the capabilities of some future PGMs and RPVs--notably cruise missiles--are sufficient to make them a factor in decisions by some countries to postpone acquiring nuclear weapons. In addition, their possession tends to serve, rather than to oppose, some goals of arms control, because they would produce less unneeded and unwanted damage, should combat occur.

Naturally, a decision to build nuclear weapons is based on considerations other than purely military ones. But superpower guarantees and suasion may tip the scales if it can be shown that precise modern missiles can do the job that a rudimentary nuclear force would do. (An

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[2]Thinking about environments in which more of the new weapons may be included in military postures leads to several concerns, which are expressed in the following questions:

1. Will the widespread presence of PGMs and RPVs make resort to military action more likely? For example, their availability might have permitted the U.S. Air Force to launch an effective surgical strike during the 1962 Cuban Missile Crisis and thus have induced President Kennedy to select that option rather than a quarantine. Therefore, by minimizing collateral damage, will they increase the decisionmakers' willingness to employ military force?

2. Will PGMs and RPVs reduce the need for nuclear weapons (by permitting accurate conventional munitions to accomplish the same objective) and thereby raise the nuclear threshold? Or, on the contrary, will PGMs increase the probability of resorting to nuclear weapons by quickly destroying existing conventional arsenals?

interesting case is that of South Korea, which feels threatened by a line of hardened artillery emplacements just north of the DMZ. These might be prime targets for a South Korean nuclear force, but a force of nonnuclear PGMs (e.g., CLGP with laser designators carried on RPVs) could be ready just as soon. Thus U.S. assistance with PGMs and RPVs might reduce South Korean nuclear motivations, while suasion--which may have been exercised when the French reversed plans to sell reprocessing facilities--would make nuclear acquisition more difficult.[3])

But the acquisition of PGMs, especially by unstable governments or terrorist groups, comprises a serious threat to transportation, rights of assembly, or even the enjoyment of urban living in societies throughout the world. The Soviets, who might once have profited from such developments, are increasingly likely to share Western apprehensions about their spread, especially since the maturing Soviet posture is coming to depend more on foreign bases and stable alliances.

The control of modern weapons available to small powers and terrorists is not the focus of the present research, however, and a number of distinctions can be made. In the hands of the superpowers and their allies, factors other than the characteristics of the weapons themselves may dominate any assessment of their operational worth: the reconnaissance and target acquisition systems that guide the weapons, the command and control systems that direct their use, the mobility systems that get the right numbers of weapons to the place of need, and the logistics systems that may have to replenish weapon stocks consumed at a very high rate.

All of these factors would make an agreement to limit third-category weapons a problem quite new in form. In addition to many of these modern weapons being easy to manufacture in the first place, their mission might be changed by simply inserting a different, tiny, microprocessor. Payload could be traded for range. And, most important, verification might be exceedingly difficult. Thus it may be much more fruitful in the analysis of early practical qualitative arms control actions to concentrate on possible constraints on large traditional weapons. But the

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[3]See the editorial on controlling reprocessing facilities in *The New York Times*, February 25, 1976, p. 36.

important class to learn more about over the *long term*, to explore in terms of understandings *along new conceptual pathways, and, ultimately*, to control, is the class of modern, mass-producible, precision weapons.

Appendix A

NOTES ON COSTS

By J. P. Large

A number of cost figures have been cited without explanation or apology in the text of this report, and a perceptive reader may note that those figures sometimes differ from numbers quoted in the public press or in government reports. Some of the possible reasons for such differences are discussed below, not in an attempt to justify the costs shown in the text and in the tables that follow but to emphasize that, in general, cost figures do not have much meaning except in a very specific context or as a rough gauge of relative resource demand at some point in time.

The date on which a weapon is procured has become much more important in the past few years because of abnormally high inflation rates. Normally, one expects the unit cost of equipment to decrease with each successive buy because of the cost-quantity effect, and it is still true that the first few units are much more costly than those produced later. Once an item is well into production, however, inflationary effects dominate learning effects, and cost increases with each successive year. Table A.1 shows examples of unit cost increases in the DoD budget from FY 1975 to FY 1976.

Table A.1

EXAMPLES OF UNIT COST INCREASES

(Amounts in $ millions)

Item	Unit Cost in FY75 Budget	Unit Cost in FY76 Budget	Percent Increase
A-6E Intruder	10.78	13.17	22
SSN-688 Nuclear submarine	193.50	245.50	27
PF Patrol frigate	62.36	95.55	53
M60 Tank	.35	.59	69
F-15 Eagle	10.51	13.25	26
Hawk	.08	.10	25
M113 Armored personnel carrier	.05	.08	60

It will be noted that those are unit costs in current or then-year dollars. They are not today's costs, and in most cases they do not represent the actual cost to the buyer to add those equipment items to the inventory.

The Comptroller's Office in Hq USAF, apparently tired of questions about the multiplicity of cost figures for a given aircraft, published Table A.2 to illustrate how seven different unit costs can exist for one aircraft and all be "correct" in some sense.

Table A.2

AIRCRAFT UNIT COST

(Amounts in $ millions)

Aircraft	Constant 1976 Dollars			Constant Base-Year Dollars	Then-Year Dollars		
	Program	Procurement	Flyaway	Flyaway	Program	Procurement	Flyaway
B-1	70.4	53.5	47.2	30.1(FY70)	87.8	72.8	64.3
E-3A	101.3	61.1	46.9	30.7(FY70)	104.1	69.7	53.6
E-4	107.5	55.7	51.7	44.5(FY74)	117.2	64.5	59.9
A-10	4.8	4.2	3.6	2.1(FY70)	5.7	5.2	4.4
F-15	15.1	12.3	10.4	6.1(FY70)	15.3	12.9	11.0
F-16	7.2	6.4	5.1	4.6(FY75)	9.2	8.3	6.6

SOURCE: Directorate of Management Analysis, Hq USAF, January 21, 1976.

The first distinction made is between constant 1976 dollars, constant base-year dollars, and then-year dollars. Constant dollars are adjusted to represent the purchasing power of a dollar in any specified year. Base-year dollars are normally those of the year of the development estimate. Then-year dollars are those actually appropriated for past years; for future years, they contain an allowance for inflation.

The next important distinction is between *program* cost, *procurement* cost, and *flyaway* cost. Program or program acquisition includes RDT&E, initial spares, ground support equipment, training equipment, technical data, and a variety of other costs, as well as the aircraft itself. Procurement cost includes all of the above except RDT&E. Flyaway cost is just the cost of the aircraft fully equipped with electronics and armament (but not such weapons as standoff missiles or rockets).

All of the above costs are useful in a particular context, but none is representative of the savings that would accrue if fewer aircraft were procured or of the incremental costs that would be incurred if more aircraft were needed. The flyaway cost of the B-1, for example, is based on a buy of 240 production aircraft. If fewer B-1s were purchased, unit cost would increase because unit cost varies inversely with quantity. For a buy of 120 B-1s, flyaway cost (in 1976 dollars) could be expected to increase from $47.2 million to about $57 million. For the unlikely case of increased production, unit cost would decline.

Cost is influenced not only by production quantity; it is also affected by production rate. Some of the missiles in the tables that follow are more expensive than others because they have been produced at an inefficient rate to reduce annual funding requirements or perhaps to keep a production line in being over a longer period of time. The cost of the Mark 48 torpedo, for example, increased by a factor of two when production rate was cut drastically. Other equipment is out of production completely, so the costs shown are of historical interest only. To restart production usually implies substantial starting costs and hence a higher unit cost than previously.

Clearly, costs do play an important part in studies of arms control, and these comments are not intended to suggest that they do not. Rather, these notes emphasize the need to understand which cost number is appropriate for a particular situation. The costs in Table A.3 are illustrative of what unit costs have been in the past or are expected to be in the future, and for preliminary studies such numbers may be useful.[1] For studies in which it is important to know how alternative forces would actually affect defense spending, these costs are inappropriate, and additional cost analysis would be needed.

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[1] In terms of the discussion above, the unit cost shown here is a flyaway cost, but that phrase seems inappropriate for land and sea systems.

Table A.3

ILLUSTRATIVE WEAPONS SYSTEM COSTS

(Amounts in $ millions)

Forces	RDT&E (then-year dollars)	Unit Cost[a] (FY75 dollars)	Annual Operating Cost (FY75 dollars)
Land Forces:			
AAH	525	2.4	1.7/helicopter
Hellfire	150	.015	
Chaparral/Vulcan	--	.75/battery .029/Chaparral	1.8/battery
Stinger	120	.006	
SHORAD	330	1.5/fire unit .022/missile	
AFAADS	185		
XM-1	370[b]	1.05	
MICV	90[b]	.265	
TOW		.003	
Dragon	65	.005	
ARSV		.175	
Cobra-TOW	40	1.28	
Improved Hawk		.096/missile	2.1/battalion
SAM-D	1650	.650	
Lance		.25/nonnuclear .5/nuclear without warhead	5.4/battalion
8" SP Howitzer			
105mm SP		.217	
155mm SP		.270	
CLGP	40		
UTTAS		2.3	.124/helicopter
Tactical Air Forces:			
F-14	600[c]	15	6/squadron (12 ac)
Phoenix	450	AWG-9 = 1.5 Missile = .33	
F-18	1500 (Est.)	6.0	3.8/squadron (12 ac)
A-6E		9.0	5.2/squadron (12 ac)
Condor		.333	
A-7E		6.4	3.6/squadron (12 ac)
A-4M		3.5	4.0/squadron (20 ac)
V/STOL (Harrier)		5.0	
F-15		12.9	18.6/squadron (24 ac)
F-16	585	8.3	14.8/squadron (24 ac)
A-10		5.2	9/squadron (24 ac)

Forces	RDT&E (then-year dollars)	Unit Cost[a] (FY75 dollars)	Annual Operating Cost (FY75 dollars)
Tactical Air Forces (continued):			
Maverick			
TV		.019	
Laser		.074	
IR		.148	
Sidewinder			
AIM-9H		.028	
AIM-9L		.035	
Sparrow		.10	
Shrike		.034	
F-5F		3.0	
Brazo		.13	
LGB		.025-.05	
HOBOS		.018	
Walleye		.03	
MGGB(GBU-15)		.239	
Naval Forces:			
CVN (Nimitz class)		1365	60/ship
CVNX		1000	50/ship
Sea Control Ship		125	4/ship
SA-3		12.6	4.3/squadron (10 ac)
P-3C		15	5.5/squadron (8 ac)
CGN		368	4.5/ship
AEGIS	355		
FFG-7		122	1/ship
LAMPS MK II		3.5	.25/helicopter
PHM		31	.65/ship
Standard			
RIM-66B		.178	
RIM-67A		.248	
RIM-66F		.433	
Harpoon		.436	
SLCM	960	.63/tactical .525/strategic	
MK 48 Torpedo		.36-.72	
Captor		.055	

SOURCES: Hearings on Department of Defense Appropriations for 1976 and prior years before a Subcommittee of the Committee on Appropriations, House of Representatives, and the Committee on Armed Services, U.S. Senate; and Service Planning Factor Manuals.

[a] Flyaway costs for aircraft; analogous costs for other weapons systems.

[b] Funds prior to FY74 excluded.

[c] Airframe only.

Appendix B

SOME POINTS FROM A STUDY FOR THE CONGRESS

A recent study, *United States/Soviet Military Balance, A Frame of Reference for the Congress*,[1] requested by Senator John C. Culver, sets forth a number of points relevant to the consideration of qualitative arms limitations. Many of the sort of evaluations made in this report are usually found only in classified sources. We include some excerpts here both to serve as a convenient reference and because the viewpoint is somewhat different from our own.

* * *

THE QUANTITATIVE BALANCE

The quantitative military balance since 1965 has shifted substantially in favor of the Soviet Union (see Table B1 ... for present status and trends)...

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Ground Forces

The numerical strength of U.S. ground forces, including Marines, has never matched Moscow's massive army. Soviet personnel strength presently is 2-1/2 times that of the U.S. establishment, and our divisions are outnumbered 9:1 (168 Soviet, 19 U.S. Army/Marine). Some 9,000 U.S. main battle tanks compare unfavorably with 34,500 in the Kremlin's armored force, which has 40,000 steel-plated personnel carriers, double the size of the U.S. contingent. Their stock of antitank (AT) missiles is almost triple ours. America has only two clear quantitative advantages: we have many more helicopters, and the U.S. Marine Corps dwarfs its Soviet counterpart, which fields a small fraction of as many men (197,000 to 12,000), has no divisions, and no organic air support.

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[1] By John M. Collins and John Steven Chwat, The Library of Congress, Congressional Research Service, January 1976.

Table B1

UNITED STATES/SOVIET NUMERICAL BALANCE

U.S. Superiority		Soviet Superiority	
Strategic Nuclear			
Bombers	MIRVs	ICBMs	SLCMs
ALCMs	Warheads	SLBMs	Air defense
Tactical Nuclear			
Fighter/attack aircraft		Missiles	
Artillery		Medium bombers	
Ground Forces			
Marines	Anti-tank weapons	Personnel	Tanks
Helicopters	Logistic tail	Divisions	Artillery
		Air defense	
Naval Forces			
Aircraft carriers		Attack submarines	
Aircraft afloat		Cruise missile ships	
		Combat boats	
		Aircraft ashore	
		Mine countermeasure ships	
Tactical Air Forces			
		Fighter/attack	
		Airlift	
Strategic Mobility Forces			
Airlift		Sealift	

Naval Forces

Ten years ago, the Soviet Navy had already outstripped the United States two-to-one in attack submarines (336 to 169), but its surface fleets had just begun to break out of their coastal cocoons and compete on high seas. Today, they have more major combatants in every category except aircraft carriers, and a virtual monopoly on surface-to-surface anti-ship cruise missiles, which are mounted on cruisers, destroyers, submarines, and small craft. The Soviets have even surpassed us in numbers of amphibious ships, ending once dramatic U.S. dominance--not because they built many more, but because we have halved our force since 1965.

Three important U.S. pluses compensate in part for otherwise lopsided statistical comparisons in Soviet favor. First, the U.S. Navy includes seven nuclear-powered surface combatants. The Soviet Navy has none (although its 75 nuclear attack and cruise missile submarines outnumber our 63). Second, U.S. carrier air power is unsurpassed. Moscow as yet has no fighter/attack aircraft afloat, and still will rely on short-range, vertical/short takeoff and landing (VSTOL) versions when ships of the Kiev Class enter active

service. Last, but surely not least, the U.S. Navy not only has more ASW aircraft afloat, but more shore-based as well (450 to 360 in the latter category, which commonly is considered a Soviet quantitative strength).

Tactical Air Forces

America's land- and carrier-based combat aircraft, excluding forces for strategic air defense, quantitatively outclassed Soviet tactical air power in 1965 as they do today. However, that comparison is deceptive, since a large segment of our naval air arm is dedicated to fleet defense. The Soviet Air Force presently has 25 percent more fighter/attack aircraft and medium bombers than the U.S. Air Force and Marine Corps combined. Total tactical air transport ratios favor the Soviet Union (500 U.S. C-130s, 800 Soviet Cubs).

. . . .

THE QUALITATIVE BALANCE

The raw quantitative balance just revealed must be conditioned by qualitative considerations, some of which benefit the United States, others the Soviet Union. A sample list, in no particular order of importance, includes: leadership; discipline; morale and motivation; education; training; combat experience; organization; command and control arrangements; staying power; and technology. The sum determines effectiveness.

Superiority in all or most of those categories can enable numerically inferior forces to compete successfully--categorically, or within limits, according to circumstances. Conversely, forces with great quantitative superiority could prove insufficient if serious shortcomings were evident in even *one* of those entries.

Coverage below simply hits a few high spots for exemplary purposes.

. . . .

Material

Technological supremacy traditionally has been a strong U.S. suit, and remains so in many areas, as Table B2 shows. The day has passed, however, when U.S. scientific ascendancy can be taken for granted. Soviet efforts already equal our own in several respects, surpass us in others and exhibit strong momentum.

Table B2

THE TECHNOLOGICAL BALANCE

U.S. Superiority	Soviet Superiority
General	
Composite materials	Commonality of components
Computers	Ease of maintenance
Guidance systems	Gas turbine engines for ships
Microtechnology	Rockets and ramjets
Night vision	
Nuclear-powered ships	
Optics; acoustics	
Submarine detection	
Submarine silencing	
Specific	
Aircraft	Armored personnel carriers
Artillery ammunition	Chemical warfare
Antisubmarine warfare	Cold weather equipment
Electronic countermeasures	Engineer bridging
Guided munitions	ICBM "Cold launch"
MIRV reliability	ICBM payload, yield
Missile accuracy	Low-level air defense
Survivable submarines	Ship size versus firepower
Target acquisition	Short-range SSM

NATO/Warsaw Pact

A wide range of qualitative considerations and constraints influence the NATO/Warsaw Pact balance.

Capabilities in the crucial center sector, for example, are conditioned especially by missions (large Soviet elements reputedly are required to enforce internal security in satellite states); the reliability of allies (some forces in the Soviet sphere might revolt in emergency, some NATO states stay neutral); mobilization speeds (Soviet ground forces fill Category 2 and 3 divisions already cadred, this country calls up Reserves and the National Guard); reinforcement times (the Soviets via short land lines, U.S. forces by sea and air); the readiness of reserves in terms of equipment and training; command structures (Soviet central authority versus NATO's need for consensus); commonality of arms, ammunition, equipment, and repair parts (all accoutrements are similar on the Soviet side, many of NATO's are not); and vulnerabilities

(NATO's installations are concentrated, the Warsaw Pact's are dispersed).

Pervasive Policy Decisions

Deliberate U.S. policy decisions account for the quantitative and/or qualitative ascendancy of Soviet armed forces in several areas. The seven summarized below overarch all others. [The seven headings are: *Quantum Instead of Incremental Improvements, Quality Instead of Quantity, Firepower Instead of Manpower, Sustained Combat Concepts, Cyclical Cutbacks, All-volunteer Force, and Money for Manpower.*]